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The Journal of Bone and Joint Surgery

CORRELATION OF CLINICAL AND ANATOMICAL FACTS LEADING TO A CONCEPTION OF THE ETIOLOGY OF CONGENITAL HIP DYSPLASIAS *

PRESIDENT'S ADDRESS

BY CARL E. BADGLEY, M.D., ANN ARBOR, MICHIGAN

This paper was not prepared for publication as a scientific article to clarify the etiology of congenital dysplasias of the hip. It was developed as a Presidential Address to stress the close interrelationship of the allied sciences, and the need for correlation of isolated facts discovered in various fields of scientific endeavor in interpreting and unraveling the mysteries of deforming and crippling conditions. Isolationism and self-sufficiency, grave dangers to specialization, cannot develop without detriment to orthopaedic surgery.

It has been our observation that too much emphasis has been paid to technical improvements and procedures in the selection of papers for our scientific programs. There has been too little appreciation and demand for scientific inquiry into the many fundamental questions of our specialty which still remain unsolved.

Therefore, in the preparation of this paper on the "Correlation of Clinical and Anatomical Facts Leading to a Conception of the Etiology of Congenital Hip Dysplasias", we have attempted to correlate isolated fundamental facts observed by scientific investigators working in diverse fields, with the numerous clinical observations accumulated in the study of congenital hip dysplasias, and to explain, if possible, the etiology of conditions.

TWO MAIN THEORIES FOR ETIOLOGY OF CONGENITAL DISLOCATION

A review of the literature concerning the etiology of congenital dislocation of the hip shows that in the first part of this century there was

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 19, 1943.

a very spirited interest in this subject, with strong exponents postulating a mechanical theory of the origin of the hip dysplasias. The accumulative evidence of sex characteristics, heredity factors, geographical and racial incidence, and the frequent occurrence of the dysplasias with associated deformities led to a second hypothesis of a primary developmental fault of the acetabulum, which has been almost universally adopted as the accepted theory for the last thirty years.

For years, we have been unable to correlate clinical facts, embryological knowledge, and anatomical findings with a theory of etiology of dislocation of the hip and hip dysplasia which is based on a primary inherent fault in the development of the acetabulum. It may be well explained in the literature, but we have not found an authentic article presenting, as proof, other evidence than the hypoplasia of the posterior acetabular roof frequently associated with the deformity. We have assumed that exponents of this hypoplasia theory explained the posterior displacement of the hip joint by the insecure support available for the head of the femur.

REVIVED INTEREST IN HIP DYSPLASIA

There has recently been a revival of interest in dysplasia of the hip joint. Increased knowledge of the serious growth disturbances produced by this maldevelopment plays an important part in this interest. Doubtless study has also been stimulated by the excellent results obtained in the early recognition and treatment of the condition initiated by Putti at the *Istituto Ortopedico Rizzoli* in 1927. Scaglietti recently reported that in 94 per cent. of 478 cases of preluxations of the hip, which demonstrated Putti's triad of diagnostic signs, the patients had excellent results with treatment in the first year of life following Putti's method of abduction and internal rotation of the hip.

In contrast to this report, Severin, from Haglund's clinic, recently reviewed 456 dislocated hips treated, according to Haglund's dictum of delayed treatment, after the patients were two years of age. This end-result study showed 7 per cent. of the hips to be in good condition, and 15 per cent. to be slightly displaced. Severe secondary changes had occurred in 51 per cent., and redislocation had occurred in 15 per cent. of the cases.

CLINICAL OBSERVATIONS

These observations, if correct, tend to point to the fact that *there is not* a primary inherent factor in the acetabulum producing dislocation, or 94 per cent. of the affected hips could not develop normally even under treatment. They also stress the necessity for a re-evaluation of the etiology. If the acetabular changes are secondary, this fact should emphasize the clinical importance of recognition of the dysplasias of the hip, in early infancy, so as to institute appropriate treatment at the earliest period possible.

Several clinical facts have seemed contradictory in the acceptance

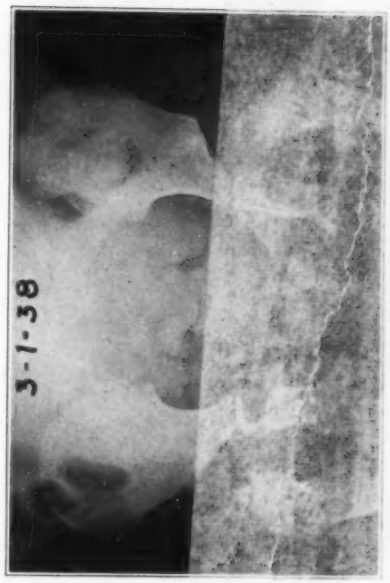

FIG. 2-B

FIG. 2-D

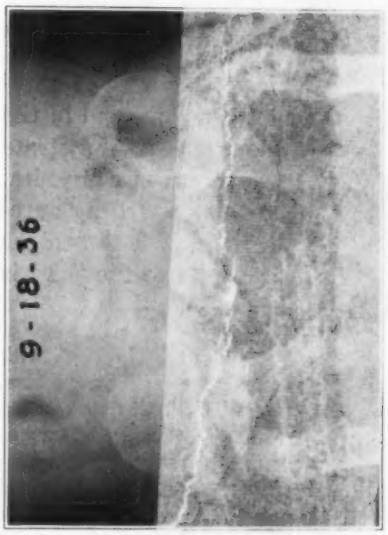

FIG. 2-A

FIG. 2-C

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FIG. 1-A

FIG. 1-B

FIG. 1-C

of the theory of primary dysplasia of the acetabulum:

First, we could not correlate such a theory with the contradictory evidence of the usual posterior displacement of the dislocated hip and the almost invariable clinical evidence of anteversion of the head and neck of the femur. From the typical position of traumatic dislocation of the hip, one would suppose that an adaptive or secondary force would produce retroversion, not anteversion.

Second, we appreciated the fact that the apparent coxa valga in these cases was essentially only an expression of the marked anteversion. This clinical fact has been pointed out by Tubby, Krida, Müller, and others, and serves to emphasize the frequency of anteversion.

Cases 1 and 2 are excellent illustrations of the importance of anteversion of the head and neck of the femur in the production, and in the recurrence of congenital dislocation of the hip. Also these cases illustrate definitely that the apparent coxa valga, so often observed in congenital dislocation of the hip, is not coxa valga at all, but is produced by anteversion of the head and neck. Roentgenograms taken with the thighs internally rotated demonstrate that the angle of the neck to the shaft is normal when the anteversion is corrected.

CASE 1. C. W. (No. 410873), a two-year-old child, was first seen in 1939, with bilateral dislocation of the hips. She presented a rather characteristic clinical picture, except for the fact that the heads of the femora were anteriorly placed, thus causing a primary anterior dislocation of the hips (Fig. 1-A). Figure 1-B demonstrates that correction of the anteversion by internal rotation and abduction without any manipulation corrected the dislocation. This position was maintained by a plaster double spica for six months. A bilateral fragmentation of the epiphysis developed in spite of the fact that no manipulation of the hips had been performed and no trauma had been inflicted. Clinically she is cured, and Figure 1-C, taken three years later with the legs in neutral position, shows maintenance of the reduction, and correction of the anteversion, but there is still an oblique acetabulum.

A correction of an anterior primary dislocation was obtained in this two-year-old child by correction of anteversion by internal rotation and abduction. This case emphasizes the importance of anteversion in the production of dislocation of the hip.

CASE 2. B. R. (No. 389466), had a typical bilateral posterior dislocation of the hips which were treated by the conventional Denucé method of reduction and plaster-spica fixation for four months. Recurrence of the dislocation with the usual anterior type of displacement occurred (Fig. 2-A). The obvious anteversion is well demonstrated in Figures 2-B and 2-C taken one week apart in neutral and internal rotation positions, respectively, a year and a half after reduction. Figure 2-D shows the result of simply a subtrochanteric derotation osteotomy on the right side. A shelf operation was performed later on the left. The derotation of the anteversion gave the better result.

We feel that this case illustrates the fact that anteversion precedes dislocation, and is a definite etiological factor for both the dislocation, and for the tendency to recurrence of the dislocation.

Third, the rather infrequent occurrence of anterior primary dislocation of the hip, associated always with coxa valga, anteversion, and anterior displacement of the head of the femur, demonstrates that, in this group of cases at least, the original displacement of the hip was anterior. McCarroll and Crego make an interesting observation on their group of ten cases of this type of luxation: "The displaced femoral head rested upon the anterior superior spine of the ilium and, as a result of this pressure, hypoplasia of the anterior rim of the acetabulum developed".

Fourth, Max Böhm's theory of the embryological origin of club-foot, as an arrest of development of the hindfoot in a foetal position, which prevents normal rotation in the development of the foot, has long interested us. The recent observations, reported by Bomfim from the *Istituto Orthopedico Rizzoli*, of the association of club-foot deformity with dysplasias of the acetabulum, show an amazingly frequent occurrence. His report showed that of a total of 364 cases of preluxation of the hip—the diagnosis complying with Putti's standards—200 presented a club-foot deformity. He investigated further from another statistical approach, and found that, out of 500 total cases of club-foot, 39 per cent. showed evidence of dislocation of the hip. The importance of recognition of this frequent association is illustrated by the following case:

CASE 3. R. A. (No. 478175), had bilateral club feet (Fig. 3-B), and was treated at an excellent hospital for two years before a congenital dislocation of the right hip and a dysplasia of the left hip were recognized. The right hip has been reduced by open reduction and a shelf operation has been done (Fig. 3-A).

This observation tends to confirm the evidence for the etiology of hip dysplasia which will be presented later.

Fifth, the true embryonically dislocated hip, seen in the multiple deformities of arthrogryposis multiplex congenita, usually demonstrates a primary anterior dislocation.

Case 4 presents the typical apparent coxa valga seen in arthrogryposis multiplex congenita (Fig. 4-A). Coxa valga here is due not to anteversion, but to the external rotation of the femur. Failure of normal rotation

FIG. 3-A

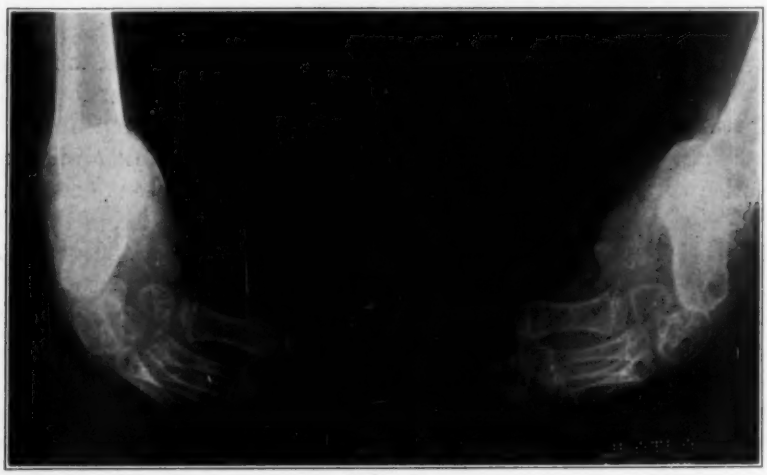

FIG. 3-B

of the limb bud, in this group of cases, prevents the resultant anteversion from developing. The coxa valga is due to the external rotation. The typical position of the dislocated hips, with the typical secondary acetabula associated with club-foot, are well demonstrated in this case.

THE SYNDROME OF ARTHROGRYPOSIS MULTIPLEX CONGENITA

In as much as the dislocation of the hip in this syndrome is the chief evidence available so far of the development of congenital dislocation

of the hip in early embryonic life, the syndrome seemed worthy of study. We recognized that Lorenz and others have discarded this group, isolating it as a teratoid dislocation differing from the ordinary postnatal development of congenital dislocation. Thus, they felt conclusions drawn from the true dislocations did not necessarily apply to the usual congenital dislocations. We, however, have learned much from our investigations of arthrogryposis multiplex congenita which we regret can be mentioned only briefly. The conclusions of our observations on this syndrome may be expressed as follows:

1. The rigidity of the joints is undoubtedly the result of the partial paralysis of the muscles of the involved extremities interfering with foetal movements. This explanation is substantiated by Murray's report from several laboratories of experiments with limb-bud transplants in regenerating paralyzed muscles, which show this same fixation of joints. Clinical evidence is also presented by the frequent report of the mother that she has felt no foetal movements.

The roentgenogram of the upper extremities in Case 4 (L. K., No. 505615), a child of four years, illustrates the characteristic position and the club hands (Fig. 4-C). It demonstrates that the architecture of the joints is well developed. The fixation of joints in arthrogryposis multiplex congenita is a result not of the architecture of the joints, but of the failure of foetal motion caused by muscle paralysis.

2. The characteristic posture of the limbs in arthrogryposis is definitely that of an arrest in development, with failure of normal rotation of the limb bud. This is an arrest of the posture at about the third or fourth month of foetal existence. The turning outward of the elbows and knees, the external rotation of the leg, and the internal rotation of the arm are characteristic early foetal positions prior to the rotation of the limb bud. The ventral surface of the lower extremities still faces dorsally, the back of the knees face each other, and the dorsal surface of the leg and thigh is in the original foetal position before rotation has occurred. The absence of the normal differentiating creases separating the trunk from the limb is significant.

Case 5, M. O'C. (No. 437683), demonstrates the characteristic posture of arthrogryposis multiplex congenita (Figs. 5-A and 5-B). The similarity of the posture of this syndrome to that of the early foetal position of the embryo is obvious on consulting the foetal positions described by His. In this case the hips are not dislocated.

Case 6, C. H. (No 318918), presents even more markedly the failure of rotation of the limb buds, and the maintenance of the foetal attitude in striking pose, with the convexities of the elbows and knees pointing outward (Fig. 6-A). Failure of normal differentiation of the shoulders and thighs from the trunk is well demonstrated in this case. The arms, which have not externally rotated nor have they gone to the vertical axis, still maintain the horizontal axis position (Figs. 6-B and 6-C). Her hips are not dislocated, but are malformed.

Compare the deformity with the stages of rotation of the normally developing limb bud as depicted by His. It will be observed that the limb buds originally extend directly lateral from the axis of the body; but, as development continues, they project more caudally. Two distinct divisions appear in the limb bud to form a basal or pelvic thigh part and a distal or leg part. The basal part continues to grow in a ventrolateral direction, while the distal part turns and grows in a ventromedian course. There is a slowly progressive, internal rotation of the basal portion, which tends to rotate the limb so that the original dorsal surface of the limb bud is turned laterally, and the original ventral surface is turned medially. This rotation occurs in opposite directions in the arm and leg. Thus in early embryonic life, the convexity of the elbow and the convexity of the knee is turned outward. At a later period of development, however, this torsion force continues to rotate the limb buds until they assume the attitude of erect posture, with the convexity of the elbow rotated dorsally and the convexity of the knee directed ventrally.

FIG. 4-A

FIG. 4-B

We believe it is obvious that the posture of the typical case of arthrogryposis multiplex congenita is analogous to the normal foetal position of the limb buds at about the end of the third month. Therefore, one must assume that there has been an arrest of development and of rotation of the limb buds. The

factors producing this arrest must be explained by the changes of marked muscle atrophy and degeneration, associated with the rigidity of joints characteristic of this clinical syndrome.

The forces of torsion have not produced the normal rotation, because these forces are the atrophic and degenerated muscles characteristic of the syndrome. The rigidity of the joints and the fixation may also be factors. Whatever the cause, the deformity is produced by the failure of normal rotation of the limb buds. The associated club feet and club hands seem to emphasize this.

The dislocation of the hip seen so frequently in these cases presents the following characteristic features:

1. It is irreducible.
2. The formation of the secondary acetabulum is characteristic.
3. There is usually an anterior displacement of the head.
4. The foetal position of the limb bud is retained.
5. There is no evidence of anteversion of the head and neck of the femur.
6. Coxa valga is apparent.

FIG. 4-C

Case 7, B. F. (No. 344026), presents the typical characteristics of the embryonic dislocation of the hip seen in arthrogryposis multiplex congenita,—apparent coxa valga and an apparent deep secondary acetabulum with a well-developed roof. A primary anterior dislocation of the hip, with the head resting on the inferior spine of the ilium, has retarded development by hypoplasia from pressure of this portion of the ilium, and has produced the apparent secondary acetabulum (Figs. 7-A, 7-B, and 7-C). The apparent coxa valga is not due to anteversion, but to a failure of rotation, and to maintenance of foetal external rotation.

We can present conclusions only, as space will not permit a full discussion of these various characteristics. The essential feature for this thesis is the evidence of a primary anterior displacement of the head, associated with external rotation of the femur.

The development of the characteristic secondary acetabulum, as

described by Farkas, is not a secondary acetabulum, but is actually failure of development of the anterior margin of the ilium because pressure by the head produces hypoplasia of its contact area on the embryonic ilium. Normal development of the anterior margin of the ilium above this pressure of the head occurs. There is no bone on the medial side of the head; it is directly against the iliacus. This has been observed in open reductions of these hips, and can be illustrated by a schematic drawing of an operative exposure, demonstrating this position and the developmental deformity (Fig. 8). This deformity of the anterior margin of the ilium is identical in location, but is greater in magnitude than that noted by McCarroll and Crego in their reported cases of primary anterior dislocation of the hip.

Case 8, R. L. M. (No. 461482), illustrates typical arthrogryposis multiplex congenita plus congenital malformation of the sacrum, involving, however, only the lower extremities. Operation on this patient's left hip disclosed the actual mechanics of the development of the secondary acetabulum. A schematic drawing from the photograph taken at the time of the operation illustrates accurately the position of the head in relation to the inferior spine of the ilium and to the hypoplasia from pressure in this part of the ilium (Fig. 8). The so-called primary hypoplasia is undoubtedly secondary to pressure of the head in malposition. So also can hypoplasia of the superior posterior margin of the acetabulum in cases of posterior dislocation of the hip be explained by pressure of the

FIG. 5-A

FIG. 5-B

anteverted head throwing the neck against the posterior superior roof, and producing a pressure aplasia. The roentgenograms show the characteristic displacement of the left hip. The right had already had a shelf operation. Figures 9-C and 9-D show that the coxa valga was caused by failure of rotation alone; no anteversion is present. Internal rotation of the femur was obtained by pulling the head down and opposite the acetabulum with Kirschner-wire traction, preliminary to the second-stage operation for reduction into the true acetabulum. The roentgenographic absence of the upper femoral epiphysis can be seen.

The roentgenograms show an apparent coxa valga. This is an apparent coxa valga deformity which is not synonymous with anteversion. There is no evidence of anteversion on open inspection at operation; the coxa valga is a result of the lateral rotation of the entire unrotated femur due to the retention of the foetal position.

Anteversion does not occur in these cases, because the rotating forces of the limb bud have been arrested in their action. Anteversion of the head and neck of the femur is a necessary developmental change, caused by the torsional forces which internally rotate the limb buds. The paralyzed muscles here have failed to produce their intrinsic purpose, torsion.

[6] The author feels it can be stated with reasonable accuracy that arthrogryposis multiplex congenita is a condition, etiology unknown, in which there has occurred early in foetal life, after the embryonic development of the muscles as shown by Middleton, a degeneration and resultant partial paralysis of the muscles of the extremities, particularly of the basal portion. This primary muscle involvement has prevented the normal rotation of the limb bud, by the loss of the normal torsion forces,—the muscles, themselves. Stiffness of the joints results from lack of foetal motion; this is in keeping with embryological evidence from limb buds transplanted into regenerating paralyzed muscle. The joints form intrinsically, but require motion even in embryonic life to maintain mobility. The club feet and club hands seen so characteristically in this group, the author feels, support Böhm's theory of embryonic arrest in club-foot deformity. These deformities are in a characteristic embryonic position in full accord with the foetal position of the arms and legs, and serve to emphasize the accuracy of the observation of failure or arrest of rotation as the etiological factor of club-foot.

The etiology of the primary anterior dislocation of the hip joint in these embryonic cases may well be the result of several factors:

1. The arrest of rotation has maintained the original reciprocal arrangement of head and acetabulum seen in the early phase of the development of the hip.

2. The resultant maintenance of external rotation has displaced the head anteriorly instead of rolling it internally into the developing socket.

3. Forces, produced by the abnormal foetal positions which fre-

quently occur in these cases, or by the contraction and tightening of the degenerated muscles, play a part.

It is recognized that dislocation of the hip does not occur in all. Other factors must be present.

RESULT OF CLINICAL STUDY

These clinical observations demonstrate:

1. Anteversion is frequently present in acetabular dysplasia.

FIG. 6-A

2. In this selected group of cases, the dislocation of the hip is primarily anterior in its original position.

3. Hypoplasia of the acetabular structures can be produced by arrest of growth from faulty pressure. This has been demonstrated in the cases of McCarroll and Crego and in our cases of arthrogryposis. Therefore, similar hypoplasia of the posterior superior margin of the acetabulum, which has been advanced as evidence of a primary inherent acetabular fault, may well be due to similar pressure, such as could be produced by anteversion of the head rotating the neck against the cartilaginous rim of the posterior superior surface of the acetabulum.

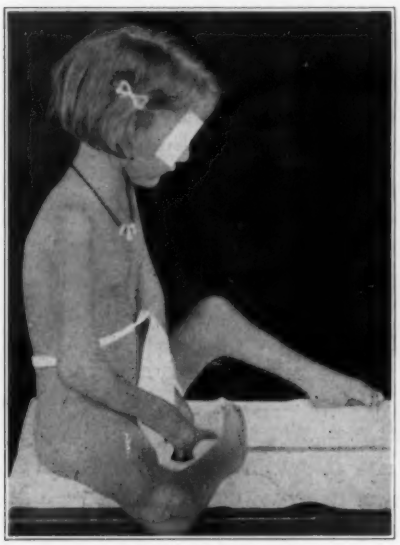

FIG. 6-B

FIG. 6-C

4. The frequency of preluxations of the hip joint associated with club feet is evidence suggestive of an embryonic arrest as a productive factor for both of these deformities.

EMBRYOLOGICAL FACTS OF SIGNIFICANCE

The embryological findings of significance in the correlation of these clinical facts must, for the sake of brevity, be expressed simply as conclusions.

1. It has been definitely demonstrated by limb-bud transplants that there is an intrinsic architectural design for the size, shape, and form of the extremities. This finding undoubtedly applies to the formation of joints as well.

2. The intrinsic factors of predetermination are of great importance in the early formative phase, but the extrinsic factors play an increasing part which becomes paramount in the later stages of development. The intrinsic development of the hip joint is formulated in its beginning toward its ultimate shape. If the extrinsic forces play the usual rôle following the usual design, a normal hip joint will result. If the extrinsic forces are abnormal, there is definite experimental evidence of their marked influence on maldevelopment.

3. The development of the hip joint must occur intrinsically with the component parts in a reciprocal relationship, because of the method of formation of the joint.

4. The torsion forces which tend to rotate the limb buds to their biped position are a necessary unit in the shape and form of the extremity, and are under intrinsic control. In other words there is a definite muscle arrangement so designed intrinsically that rotation of the limb bud develops as a characteristic of the human species. All anatomists have recognized this torsion but, curiously

FIG. 7-A

FIG. 7-B

FIG. 7-C

enough, they have not emphasized its clinical importance except as a key to the understanding of anatomical relations for teaching purposes.

Although torsion occurs throughout the limb bud, its greatest change is noted at the hip joint. The necessary alteration from the foetal to the mature position of the limb requires a 90-degree rotation with the hip joint as the axis. Howell points out that the position of the head must alter as a necessary corollary of the postural change of the leg.

ANATOMICAL STUDIES

1. Extensive anatomical studies by various authors of foetal skeletons have shown an increasing anteversion of the head and neck during embryonic life. It has been shown that anteversion increases from zero in the first two months to 35 degrees of anteversion normally at birth. These authors all agree that the anteversion develops normally during foetal life, and diminishes after birth. They disagree as to the cause for anteversion. They agree that abnormal anteversion is a definite factor in the production of dysplasia of the acetabulum, with dislocation of the hip resulting as a secondary phenomenon.

FIG. 8

2. Dega's extensive investigations and measurements of 100 foetal skeletons demonstrate the continuous reciprocal arrangement of the components of the head and socket in normal development, with anteversion developing gradually in the foetus, and the caudal angle of the acetabulum increasing with it, whereas the ventral angle of the acetabulum keeps in line with the torsion of the femur.

Le Damany, in 1908, presented an interesting conception of the mechanical cause of hip dysplasia, which stresses anterior dislocation of the hip as the primary position of deformity. His work is most interesting, and includes many valuable anatomical facts. His theories were accepted by Murk Jansen, but however interesting, they have not been generally accepted; yet we are in accord with much of his reasoning. Strangely enough Le Damany recognized the foetal rotation of the limb bud in the arm, but failed to see that in the lower extremity a similar rotation occurred in an opposite direction; this would have given him the explanation he was looking for to explain torsion, which he attributed to mechanical instead of intrinsic factors.

Le Damany observed that the relationship of the axis of the plane of the acetabulum to the head and neck of the femur in various animals was consistently at right angles, with the exception of man. In the newborn child, because of the normal anteversion of 35 degrees, this axis angle was altered to an approximately normal angle of 60 degrees. If this angle became more marked than 60 degrees, dislocation was apt to occur, particularly when the hip changed from its foetal flexed position to the extended one after birth.

The increase in anteversion from zero to 35 degrees during a foetal development of the head and neck of the femur he attributed to a torsion force, produced by several factors. An unusually long femur, the large size of the head of the human foetus, the pelvic girdle requiring the folded position of the foetus, and the pressure of uterine-muscle contraction on the flexed knee were peculiar features of human foetal development. The pressure of the uterine muscle forced the long lever of the femur against the broad pelvis, curving the femur anteriorly, and producing a torsion force which rotated the femoral shaft internally. The counterforce of the acetabulum pressing against the head of the femur rolled the head and neck of the femur on the diaphysis, thus increasing the anteversion. An abnormal force or tight coverings of the foetus increased the anteversion, so that the head pointed anteriorly out of the socket, and the socket flattened. On extension of such a hip, the head would be pulled forward out of the socket, and the capsule would be sucked into the acetabulum. He concluded that treatment not only required reduction of the displaced head, but that internal rotation was essential to correct the anteversion.

We believe that the force and mechanics, which Le Damany was searching for as a cause of these anatomical changes, can be explained on the basis of inherent factors producing the normal rotation of the hip from the embryonic to the mature position.

ETIOLOGY OF CONGENITAL HIP DYSPLASIAS

Our thesis for the etiology of congenital hip dysplasia and congenital dislocation of the hip is based on the conception that a primary dysplasia of the hip is produced by an increased anteversion of the head, with a loss of reciprocal position in the acetabulum. An anterior primary position for the head and a flat socket then develop, with the possible result of the hip dislocating and migrating posteriorly because of the anatomical location of the acetabulum. The mechanism which displaces the head is explained by the following theory:

Congenital dysplasia of the hip joint is evidence of the embryonic arrest of rotation of the foetal limb. This theory is based upon definite anatomical evidence of the adaptive changes of the position of the articulations, the arrangement of the skeletal musculature and its innervation, and the accompanying obvious torsion of the long bones which can only be explained by the gradual rotation of the limb bud from the

horizontal axis of its origin to the vertical axis which is necessary for bipedal progression.

THE NORMAL HIP DEVELOPMENT

It is the author's conception that intrinsic forces are so formed in the early embryological life that, in the normal uninterrupted development of the foetus, the inherent rotation of the limb bud produces the normally developed mature position of the limb, which is essential for correct function in the upright posture. The rotation of the limb buds for the human species is as predetermined a developmental factor as the intrinsic shape, size, and form of the bones which compose the limb.

Although there is an intrinsic design early in foetal life, with factors, such as muscles, developing in a consistent pattern to produce the limb inherent to the species, it is essential that the extrinsic factors continue to exert their influence according to a normal pattern to evolve a normal fully developed product. Thus in arthrogryposis multiplex congenita there is evidence of the intrinsic development of the normal design of the hip joint, with an alteration in the normal forces of torsion—the muscles—which are weakened or paralyzed by degeneration. The muscles originally were formed and attached intrinsically for the purpose of the predetermined development. The muscle action in itself becomes an extrinsic factor in the development of the hip joint on a predetermined or intrinsic pattern. The paralysis of the muscle removes this extrinsic force of torsion or rotation, so that as a secondary factor maldevelopment of the hip joint results, even to the extent of dislocation.

It is doubtless necessary to stress that the adaptive changes of the limb bud from the horizontal axis to the vertical axis of the lower extremity are not complete at birth, but progress at least during the first year of life, and most probably are still continued until growth of the limbs has ceased. There is a progressive correlated relationship in the alteration of position, which must have chronological perfection to produce a final end product normal in its design.

FIG. 9-A

The primitive hip joint in early

FIG. 9-B

FIG. 9-D

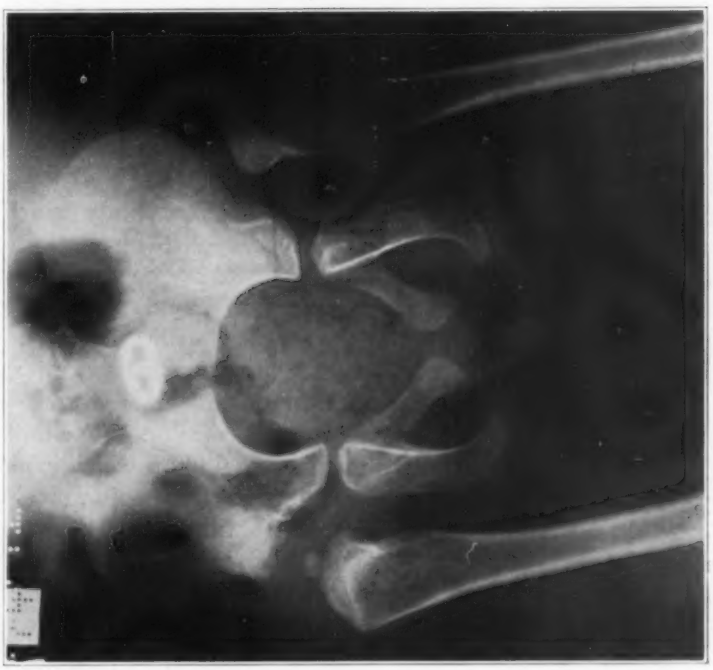

FIG. 9-C

embryonic life is formed properly for its components in their position at that phase. It is essential that, as the limb bud rotates gradually but consistently through an axis of approximately 90 degrees at the hip joint, the head of the femur alter its relationship to the developing os innominatum and acetabulum by internal rotation. The resistance of the acetabulum to the head of the femur, rotating internally through the inherent force of the muscles producing torsion on the femur, develops physiologically an increasing anteversion by the rotation of the head and neck of the femur at the diaphysis junction, as theorized by Le Damany. Also, in the author's opinion, the stimulus of the increasing pressure thus produced on the back of the socket stimulates the deepening of the socket and the increased growth of the posterior rim of the acetabulum.

The reciprocal relationship of the head of the femur and the socket normally develops chronologically, and, in the alteration from the embryonic to the biped position, by extrinsic adaptation to the inherent ultimate functional position of the joint for the human species. Thus the ultimate shape of the mature socket and head and neck of the femur is acquired adaptively, by perfect timing in the alteration of the reciprocal relations of the head of the femur and the acetabulum, and is accompanied by growth changes which develop secondary to these extrinsic forces of rotation.

The original architectural design of the early development of the hip is thus gradually changed to the characteristics of the mature hip.

This explanation of the development of the normal hip joint is undoubtedly sound. The same line of reasoning enables us to apply this knowledge to the abnormal development seen in hip dysplasias.

ABNORMAL DEVELOPMENT

From our findings in arthrogryposis multiplex congenita, the following hypothesis may be advanced:

Interference with the normal rotation of the limb buds, which produces an interruption in the continuous chronological turning in of the head on the socket, with even temporary arrest of the process, allows the head to mold itself and the acetabulum abnormally, by the extrinsic factor of loss of the normal reciprocal relationship of the compact parts. The head fails to rotate inward, and the socket becomes shallow, interfering with the future normal development, and producing mild dysplasia of the hip. A more serious interference with normal rotation of the limb bud may block the head from turning into this acetabulum which is already malshaped by the loss of the normal stimulus of pressure of the reciprocal part of the head. The torsion force still continuing, or resuming its function after a period of delay, will produce an increasing anteversion over that normally produced, because of the resistance of such a malformed socket to the proper turning in of the head. A greater or more extensive dysplasia of the acetabulum then develops, with an increased anteversion which may lead eventually to dislocation.

Therefore, any abnormality which prevents the maintenance of the reciprocal relationship of the head to the acetabulum, in its changing planes from the early foetal position to the vertical axis of the biped, will produce extrinsic factors which alter the proper development of the acetabulum and head. This in turn will produce acetabular dysplasia, anteversion of the neck, and even dislocation of the hip. These changes are secondary and accommodative to the primary failure of rotation.

Therefore, it is emphasized, they are correctible even after birth in the first year of life, simply by maintaining internal rotation and abduction to aid the torsional forces of internal rotation. It is essential to recognize that the process of adaptation of the hip joint to the upright attitude continues at least through the first year of postnatal life. Thus Putti's method of treatment of abduction and internal rotation in infancy can well produce normal hips out of preluxated ones. *The lateral position of the capitate epiphysis in Putti's triad is evidence of anteversion, not dislocation.* It is recognized that after birth there is a progressive retroversion of the head and neck from the natal 35 degrees to the adult 15 degrees of anteversion.

CONCLUSIONS

In conclusion it is our opinion that dysplasia of the hip is the result of failure of normal rotation of the limb bud, by either intrinsic or extrinsic factors, with a resultant secondary flattening of the socket and anteversion of the head and neck, which may produce an anterior displacement of the femoral head.

The normal hip development requires months of continued adjustment before the mature socket is formed. Similarly, the factors leading to dislocation of the hip require months for its maldevelopment.

The anteversion of the head secondarily produces the flat socket. The anteverted femoral head points anteriorly, with the neck lying against the posterior rim of the socket, and with the trochanter posteriorly. Hypoplasia of the posterior rim results from this faulty pressure. The flat socket does not maintain the head in position. A gradual posterior displacement of the head and neck occurs as a result of the greater angle of the caudal position of the triangular shaped os innominatum, with the acetabulum at its apex, and is probably aided by the pull of the gluteal muscle.

SUMMARY

Congenital dislocation of the hip is, then, a slowly developing deformity, secondary to anteversion of the head and neck and a resultant secondary hypoplasia of the acetabulum, which are primarily produced by an embryonic interference in the maintenance of the reciprocal relationship of the head of the femur to the socket during the rotation of the limb buds, which is intrinsically characteristic of the human species.

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SOME SURGICAL LESSONS OF THE WAR *

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Brigadier General, Royal Army Medical Corps, and Consulting Orthopaedic Surgeon to the British Army

It is natural and of value to compare the organization and the practice of today with our experience in the Great War, or what used to be called the Great War, of 1914 to 1918.

ORGANIZATION

In 1939 the organization for the treatment of the wounded in Britain was handed over, by a decision of the Cabinet, to the Emergency Hospital Service of the Ministry of Health, always referred to as the E.M.S. This decision was taken because it was thought that the number of air-raid casualties would reach astronomical figures. As both soldiers and civilians in Britain would be equally exposed to this form of attack, a single hospital service was organized. The Army Medical Service was responsible for the handling of casualties overseas, and had a certain number of static hospitals in Britain, but in the main, the wounded on arrival back from the Continent were to be looked after by the E.M.S. This plan was followed, and the influx of wounded who arrived at the various ports in Southeast England following the evacuation of the British Expeditionary Force from Dunkirk, were treated mainly in civil hospitals.

Orthopaedic Centres, some nineteen in all, had been developed, to which patients falling within the definition of orthopaedics were sent. This definition dates from 1916, or thereabouts, and was accepted by both the Ministry of Health and the War Office. The Ministry's instruction reads:

"The type of case to be sent to an Orthopaedic Centre should be:

a. Fractures.
b. Deformities of the extremities and spine.
c. Diseases, derangements, and disabilities of joints, including the spine.
d. Injuries of peripheral nerves."

Army Orthopaedics

Now with the return of the Army from overseas, it was clear that if all this material was to be segregated in E.M.S. Orthopaedic Centres, the Army Medical Service would suffer, and the training of the Army surgeons, nurses, and orderlies would be impossible. It would be equally impossible to keep up the enthusiasm and the standard of work, if patients were

* This address was prepared for the Annual Meeting of The American Academy of Orthopaedic Surgeons held in Chicago in January 1943, but General Bristow was not able to reach Chicago in time for the Meeting.

immediately transferred to the E.M.S. after they had received first-aid treatment. The personnel of the surgical side of an Army Hospital will not be, and should not be, satisfied to act merely as sorting-room officers.

An Orthopaedic Department within the Service was organized in 1940, and fifteen orthopaedic sections were formed and attached to the stationary Army Hospitals in Britain. Patients falling within the definition of orthopaedics were segregated and looked after by trained orthopaedic surgeons. Orthopaedic Out-Patient Departments, together with the necessary ancillary services, were developed, and the Army Hospitals now possess complete Orthopaedic Departments as we know it in our civil hospitals in peacetime.

These orthopaedic sections were treated generously, but, even so, the bed accommodation had to be increased by attaching to each the whole or part of an auxiliary hospital, under the aegis of the British Red Cross

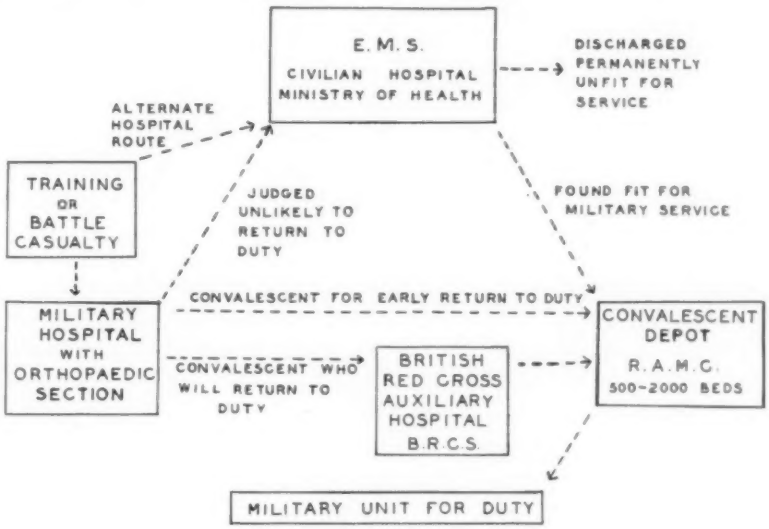

FIG. 1

Society, but with the admission and discharge of the patients and their treatment controlled by regular weekly visits of the orthopaedic specialist from the main Centre. In this way, patients with legs or arms in plaster, whose fractures are perhaps undergoing consolidation, are kept under the control of the same surgical team throughout their treatment.

The final stage of convalescence is undertaken at the Command Convalescent Depot, still controlled by the Royal Army Medical Corps, but a military organization, and not a hospital. Men going to the Convalescent Depot should be fit to return to their unit in from four to six weeks, and only such men should be sent to the Depot.

This organization has proved workable, and the American Army in Britain will probably follow a somewhat similar pattern,—that is, will form a Convalescent Depot where the men can convalesce, receive their physical

treatment, and be hardened before returning to their units. The scheme we employ is shown graphically in Figure 1.

Some of you will remember the orthopaedic organization which Sir Robert Jones created in the Great War, and the outstanding service which this great master of surgery gave to the wounded soldier. Called in to help by the late Sir Alfred Keogh, the Director General, Sir Robert Jones, starting from scratch, built up an organization which in the end controlled some 30,000 beds. The value of his work, of his example, and of his splendid personality are known to you. In so far as is possible, it has been my aim to follow the pattern he created, in advising the Army in the formation and organization of its orthopaedic service. There are complications, in that the E.M.S. also runs an orthopaedic service, but there is ample room for both, and each has its part to play. Most of us believe that the serving soldier who is injured and who is likely to be fit to serve again, is better cared for in a military than in a civil hospital. It is not a question of surgical skill, nursing, the hospital buildings, equipment, or ancillary services. It is no reflection on the E.M.S. It is merely the fact that the whole military atmosphere, call it military discipline if you will, is necessarily lacking in the non-service hospital. For the soldier so badly injured that he will not serve again, the exact reverse is true, and such a patient is better off in a civilian than in an Army hospital.

Arrangements Overseas

In the Middle East, an orthopaedic service was developed which ran on lines roughly parallel to those at home. Brigadier Dudley Buxton was sent out as Consulting Orthopaedic Surgeon, and there is no shadow of doubt, but that he organized and controlled a most efficient orthopaedic service. In discussing detail, I shall borrow freely from his experience, particularly with regard to recent experience in the splinting of fractures and joint injuries, and the problems connected with their transport.

Liaison with American Surgeons

Liaison with American medical services was established early. The American Hospital in Britain, whose personnel arrived in London in the middle of a "blitz", was the first link. The arrangements of orthopaedic services in the E.M.S. were a little difficult at that time, and the American Hospital in Britain took over a section of a large general hospital, housed in a mental institution in the country, and there ran an efficient orthopaedic service. Geographically placed as they were, the patients reached them mostly after primary-wound treatment had been carried out. The blitz quieted down, and the American group finally moved to the Churchill Hospital at Oxford, their own hospital. When America came into the War, the organization had fulfilled its purpose, its work was done, and the men split off to various services, but the close liaison continues.

Dr. Rex Diveley sits as a member of the small Committee of senior

orthopaedic surgeons, who represent the Ministry of Health, the Pensions, and the three fighting services, under the Chairmanship of Mr. Tom Fairbank, where all matters of policy are ventilated and freely discussed. There is full agreement on all matters of importance.

I have been around your hospitals, and I can tell you from first-hand knowledge that the American soldier is well cared for. You will find some British in American hospitals, and you will find Americans in ours. If an American soldier is injured in training, he is taken to the nearest hospital, and the appropriate headquarters is notified. A Consultant is sent to see him, and, if it is considered advisable, to transfer him, so that he may be taken care of by his own people.

At the Base Hospital

There are certain points of interest which we have learned in the treatment of the injured soldier at the Base Hospital. He may have become a casualty in the line, or may have been injured in training. It is the tempo of their training and the strenuous courses which these men undergo to fit them for modern warfare which have made the problem different from what we knew before. I will not weary you with figures of leg fractures caused by motorcycle accidents, but one report is really of interest. In one year in the Middle East, the number of patients sustaining fractures due to causes other than gunshot wounds was 484 officers and 7,641 other ranks. This figure gives some idea of the volume of orthopaedic work which will be met with even in quiet times, and with no great influx of battle casualties.

Air-Raid Casualties in Britain

To the end of 1941, the published figures show that in Britain 43,667 people were killed, and 50,387, who were seriously injured by air attack, were admitted to hospital.

The arrangements and organization of the E.M.S. worked well, and magnificent work was done by many surgeons, doctors, and nurses under trying and difficult conditions. Improvised operating theaters, improvised lighting, and the lack of the main water supply called for courage and resource, self-sacrifice, and a real devotion to duty. These qualities were not wanting in the men and women of Britain.

The surgery which is necessary in these conditions approximates closely the surgery of the forward area which we have discussed in describing the handling of battle casualties, but no one who has not experienced it can visualize the indescribable dirtiness which falling masonry produces. A patient is literally ingrained with dust. The extraordinary effects of blast have been many times described, and the blasting effects of modern explosives are again something which we experienced for the first time.

In the Base Hospitals, patients from the battle area, or those who were air-raid casualties, with fractures and injuries of the extremities and spine, are, in Britain, segregated for the most part in the Orthopaedic

Centres. Patients with injuries of the peripheral nerves are still further segregated into three Centres in England and two in Scotland.

Three Orthopaedic Centres in England were selected to take care of all Army patients with peripheral-nerve injuries. The bulk of civilians with nerve injuries resulting from air raids also were sent to them.

Up to the end of 1942, 1,316 patients with injuries to peripheral nerves were admitted and cared for in the three English Centres.

This segregation within segregation was organized because it was felt that an intensive study of these nerve injuries was called for, if we were going to advance our knowledge. An analysis of this total shows that the ulnar nerve was the single nerve most commonly involved with 328 cases, followed by the radial or musculospiral with 234, and the median with 228. Lesions of the sciatic trunk numbered ninety-four. The external popliteal (138) was more often affected than the internal popliteal alone which was involved in fifty-two cases. The brachial plexus was injured in 132 patients. Of the 1,316 patients, 436 were operated upon, or roughly 33 per cent.

TREATMENT

Gunshot Wounds

Turning from this brief consideration of the organization, we pass on to the treatment and transport of the wounded. With regard to first-aid treatment and transport to the dressing station, there is nothing new to say. As always the sooner the patient can reach the place at which he comes under the care of the surgeon in the forward area, the better his chances.

In the present War, the tempo has changed, and speed, mechanized speed, has completely altered the arrangements necessary in the forward areas. The organization as we knew it in 1914, both in Field Ambulances and Casualty Clearing Stations, has been changed, and the advisability of bringing the surgeon as far forward as possible has resulted in the formation of mobile surgical teams, with their own independent transport.

We are concerned with wounds of the extremities; and, in the management of gunshot wounds, the treatment of shock and hemorrhage, and the prevention of infection are now as always the primary consideration. The blood-transfusion service has won golden opinions, and the treatment of shock by this means, combined with rest, warmth, and fluids is well known to you.

Sulphonamide therapy is the outstanding new feature of wound treatment in this War. Its value by oral administration has been proved.

Buxton recommends that a patient with a large bone injury should have from twenty to twenty-five grams in the first five to seven days. Its exact value, as applied locally to the wound, is still a matter of debate, but whatever value is placed upon its use locally, it is very certain that it cannot take the place of the surgical cleansing of the wound,—the wound toilet. The practice recommended is excision of the bruised skin

edges—the removal of one-eighth of an inch of skin should suffice—and the excision of damaged muscle. In some wounds, such as in the thigh, a transverse incision is made in the deep fascia at the top and bottom of the wound to ensure free drainage and to prevent the bottling up under the fascia of blood or exudate. The surface is then dusted with sulphonamide powder, and is covered with a layer of vaseline gauze. The word "pack" is unfortunate, as the wound is not packed or plugged; a layer of vaseline gauze suffices, with gauze or wool over this.

Sulphonamide applied locally must be used with discretion. It has been shown by animal experimentation that sulphonamide in too great concentration will damage a peripheral nerve even when the sheath is intact. We have met patients who had severe peripheral-nerve damage following injection of sulphonamide in suspension. Sulphonamide should be insufflated or dusted onto the wound and not poured in bulk.

In the forward area, wounds should never be sutured. This is the old teaching and it is still true. Consulting surgeons from the Middle East have found it necessary to stress this point again and again, for there seems to exists for some a fatal fascination to suture.

With the wound toilet completed, and sulphonamide applied, it is essential to see that the dressing which covers the wound is fixed firmly enough to remain in place. It can be held by a piece of strapping, the limb being shaved to avoid painful tension on a hairy leg. In wounds of the extremities, a large dressing is held by plaster of Paris.

Skin-tight plasters, with padding over bony points, is the method of choice. The valuable pioneer work of Orr in the later stages of the last War, and in the years that followed, have borne fruit. Trueta, as the result of his experience in the Spanish War, advocated the use of plaster in the same way, and the method is now universally adopted with certain modifications. The skin-tight plaster, applied to a limb following an efficient wound toilet, provides rest and fixation, allows free drainage, and gives support to the soft tissues. It is used with equal advantage whether the wound is complicated by a fracture or not. But the skin-tight plaster, although it provides support and fixation up to a point, cannot take the place of traction. With fractures of the femur, certain fractures of the tibia, and in gunshot wounds of the knee joint, traction is essential.

Tobruk Plaster

The "Tobruk plaster", as used for the treatment of a fractured femur, was demonstrated in the hospital at Pyrford by Buxton, who had just arrived back from the Middle East.

When the wound toilet has been completed, tension has been relieved by transverse division of deep fascia, and a big dressing has been put on, skin traction by one-way elastoplast is applied, the malleoli being protected. A weight and pulley are attached temporarily to keep up moderate traction. The knee is flexed 10 degrees by suspension to

some overhead structure, and a skin-tight plaster is applied from the groin to the toes, with the foot at a right angle. The plaster is strengthened posteriorly. Two large holes are cut about the malleoli to allow the elastoplast traction a free exit. As soon as the plaster is set, a Thomas knee splint with a big ring is put on, the elastoplast traction is tied to the end in the usual way, and the ring is made to fit by putting padding between it and the plaster on the outer side. The plaster is then split from top to bottom, and this is essential if the patient is going to be moved. No skin-tight plaster should ever be applied to a patient who is going to be evacuated and transported to the Base Hospital unless this plaster is split. Disasters have occurred and will occur unless this is done. In the Middle East it was an order.

The Thomas splint is made firm to the plaster either by bandaging or by incorporating the side bars in a plaster bandage in the thigh and calf regions. A record of date, a diagram of the wound, and any other note is made in indelible pencil on that part of the plaster which will not be soaked by discharge. Fixation by this technique has proved very satisfactory, and the patients have traveled well.

Plaster Spica

The use of a plaster spica for wounds in the region of the hip, buttock, or upper third of the thigh has given rise to a wide divergence of opinion. The experience has been that in these patients plaster sores are very prone to develop, owing to the difficulties of transportation. Many such spicas have had to be removed at some stage in the journey and on hospital ships. It was the same in the last War, and you will remember that Sir Robert Jones strongly advocated the abduction frame. This apparatus has proved too bulky for use in forward areas, although it is still of service at the Base Hospital. We keep these frames at our base hospitals in England, and only recently I have found one invaluable to transport a patient some eighty miles. He was an officer whose parachute failed to function properly in a practice jump. He sustained a compression fracture of the third lumbar, and a comminuted fracture of the upper third of the right femur. To have put on a spica would have meant a fairly long anaesthesia, and then the discomfort of the drying period for a patient already suffering from shock. He traveled perfectly and in complete comfort in his abduction frame; skin traction immobilized the femur satisfactorily. In some sixteen weeks he was on duty at a Staff College, and will be none the worse for the incident.

The majority of surgeons condemn the spica, although it is fair to say some speak well of it, and I saw one very recently in an American hospital which had been put on by a British surgeon in North Africa. The patient was in such good shape that the spica did not need changing on arrival in England. (It is interesting in passing to note that both the surgeon and the plaster and indeed all his supplies had been dropped by parachute.)

If the hip spica is condemned by many, the shoulder spica as a splint for use during transport is condemned by practically all surgeons. Again to quote Buxton, writing to me nearly a year ago, he said the arm fractures did well and generally fell into alignment when he ceased using the spica. The secret of success in treating fractures of the humerus is surely simplicity,—a collar and cuff sling, and a plaster splint, a slab from the nape of the neck over the arm, around the elbow, and up to the axilla on the inner side. A few ties around the arm, of either plaster or bandage, keep the slab in place.

Amputations

Time will not permit of any discussion of amputations, but I must report to you that all experience shows that amputations done in forward areas, when the patient is going to be evacuated, must never be closed. The flap must not be sutured, even if drainage at the sides is employed. Amputation should be performed as low down in the limb as possible, cutting skin flaps and sewing them back, but never closing them. A vaseline-gauze dressing is applied.

Summary

To recapitulate, the same old mistakes, which we learned to avoid during the Great War, have given the most trouble.

We must remind ourselves that wounds must be left open and not sutured, that amputation flaps must not be closed, that plugging of wounds must be avoided, that vaseline gauze should be used as a covering not as a plug, and that skin must not be sacrificed unnecessarily in performing a wound toilet.

We must remember to fix the foot at a right angle and not in equinus, that fractures require traction as well as plaster fixation to give them the necessary rest, and that the fixation must be as nearly as possible absolute.

Peripheral-Nerve Injury

Up to the present no very striking differences have arisen since the Medical Research Council published their report on this subject, immediately following the last War, and the end results, or I should say intermediate results, at present available fall into line with the experiences of that time. Prof. Harry Platt and I reported the end-result survey at the International Surgical Congress in London in 1920, and drew certain conclusions which still seem, on the whole, to represent the true state of affairs, and it is not a very promising picture. Among the changes which have taken place, it may be mentioned that the old terms epicritic and protopathic are no longer used, and I would advise any of you who are interested to read a brilliant critical review by Walshe[1], the distinguished neurologist.

The sweat test is of value, and is an objective finding, largely worked out by Guttmann in Oxford. We did not use this method in 1914 to 1920,

but it is I think promising as a diagnostic aid and as an added method in estimating recovery.

The work of Captain Weddell on action potential changes in muscles, which will be shortly published, is a definite advance, and may well assist in estimating recovery by demonstrating down growth of the new axons.

Regarding surgical technique, fine stainless-steel wire is being used in one Centre as the suture material. This wire is specially drawn, and has a diameter of .0018 of an inch, about the thickness of a human hair. It is very fine in gauge, smooth, and provokes no tissue reaction.

In 1940, Young and Medawar introduced a coagulable plasma, colloquially spoken of as "fibrin glue", for the joining of peripheral nerves in animal experiments. This has been used in the human, but its use is very limited, as it cannot be employed if there is any tension. Its main value would be in fixing the ends of a nerve graft and especially the small cable grafts. Unfortunately, however, in spite of the promising results undoubtedly obtained by nerve grafting in animals, there is no evidence as yet that this procedure is of any real use in bridging gaps in the nerves of the limbs in man. I would refer you again to the reports of the Medical Research Council and of Prof. Platt's and my end-result survey; the position remains today as it was then, some twenty odd years ago. Some axons sometimes find their way through a graft, but not in sufficient numbers to restore useful function. There is only one way to repair a nerve defect and that is to carry out end-to-end suture.

Injuries in Training

In the stationary hospitals and in base-hospital areas there is a vast amount of work for the orthopaedic surgeon, altogether apart from battle casualties. The fracture problem as has been indicated is of staggering dimensions, and while the major fracture—the femur or the tibia—tends to interest us most, it is with the minor fracture and the minor injury that much good work can be done. Moreover, the correct handling of these and allied minor injuries will save manpower which is the most essential contribution we can make to the war effort.

A month or two ago, the orthopaedic specialists serving in Britain had a conference, and we discussed the problems which were giving us the most trouble. The clinical problems included:

1. Internal derangement of the knee.
2. Foot strain.
3. Fractures of the os calcis.
4. Fractures of the carpal scaphoid.
5. Minor injuries of the hand.
6. Injuries occurring in parachute troops.

These are all conditions which are common, and we wanted to discuss our difficulties, arrive at some conclusion as to the best method of treat-

ment, and come to an agreed policy as to the right disposal. Just a final word about some of them.

Internal Derangement of the Knee. It was generally agreed that the very greatest care must be exercised in arriving at the diagnosis of cartilage injury, and that operations on the knee were less successful in soldiers than in civilians. This may be due to too early return to work, and to the extreme severity and strain of training,—such training as includes the assault course. We felt that a considerably longer convalescence was needed, before the soldier was fit for full duty in the highest category, and that twelve weeks was often required. Again no operation should be performed unless the surgeon was very sure of his diagnosis and had tried out the joint with provocative physical therapy; and yet again in the soldier, no operation should be performed in the presence of laxity of the cruciate ligaments or a mild degree of chronic arthritis.

Foot Strain, another frequent cause of wastage, calls for constant care, and here the fault has been largely due to a failure to appreciate the need for a preliminary period of rest. The soldier complaining of pain in his feet should be examined most carefully, and his true degree of disability assessed. It is easy in a busy and crowded Out-Patient Department to slur over the history-taking and the examination, and recommend exercises or physical treatment, when what the man needs is rest and relief from strain for a few days, before these more active measures to build up muscles and adjust posture can be profitably undertaken. In general we avoid operations on the soldier's foot, with the exception of the straightening of a single hammer toe which is giving rise to symptoms. We have found from experience that the operations on the hallux, so successful in peacetime, seldom succeed in retaining a man in a high category.

Fractures of the os calcis are more common than in peacetime. They are produced by land mines, by a bomb which goes off between decks, and have occurred also in men who slide down the side of a sinking ship and hit their heels against the projecting bilge on the hull. Many of these fractures are hopelessly comminuted, but then generally become painlessly ankylosed, but if not, the joint is arthrodesed. Prolonged immobilization in plaster has a great tendency to produce a stiff useless foot. We have arrived, temporarily at any rate, at a policy as to their treatment, after a survey of some seventy cases in one hospital, where the procedure is as follows:

1. In all cases with displacement and joint involvement, reduction is attempted with an Erhalt skewer.

2. *If good reduction* is obtained, the foot is immobilized in plaster, with the pin incorporated for one month. The leg is cradled on a Braun's frame with the heel free, and gentle exercise, avoiding dorsiflexion, is given for one month. Full exercises are given, freedom in bed is permitted, and crutches are allowed, but no weight-bearing until the end of the fourth month.

I will not weary you with the details of treatment of the other types.

Fractures of the carpal scaphoid have had satisfactory results if they have been diagnosed early, reduced, and held fixed and protected until consolidated. If they have been seen late, or if an old fracture has been revealed by roentgenographic examination, disappointing results have been obtained when they have been submitted to either drilling or grafting operations. So much has been written about successful grafting that a note of warning must be sounded; it is very much the exception for a soldier, who has a fractured scaphoid which has been grafted, to continue in the Army, except in a low category. He cannot handle a rifle. Many experienced surgeons are rapidly coming to the conclusion that this operation has no place in the treatment of the soldier.

Much could be said on the treatment of minor injuries: the need for early movement, and the avoidance of prolonged splinting, especially in the hand; the care that should be exercised to see that a plaster slab never impinges on the palm distal to the proximal palmar crease to avoid stiffening the metacarpophalangeal range. There is much of interest to be learned from those who are handling the injuries peculiar to parachute troops,—such as diastasis of the ankle (which is easy to miss), the strained back of the man who reaches hospital on a stretcher, and the fractured spine of one who walks there. But there is not now opportunity to discuss these interesting problems.

In conclusion, enough has been said to make it clear that the orthopaedic surgeon has a part to play, and a big part. The injuries of the locomotor system form a large proportion of the battle casualties which reach the Base Hospital, and much of the work is of intense interest; it is easy then to give our best. However, the orthopaedic surgeon has a vital part to play in the quiet intervals, and the work then is less spectacular. The minor breakdown, the minor injuries in training, the care of foot defects, the care of posture, and the minor fractures of fingers and toes are the injuries where too we must give of our best. We can help to save manpower and return a man in the minimum time to his unit or to industry.

I am often asked what position will men get if they come into the Army. Will they have as much work to do and will that work be as interesting as that which they are doing as civilians, will they get plenty of operating, will they be accepted with the rank of Major, and what are the chances of promotion? Gentlemen, for the credit of our profession, and for the credit of our specialty, let us look at these things from a different angle, for I believe it is what we have to give and not what we have to get which finally counts.

1. Walshe, F. M. R.: The Anatomy and Physiology of Cutaneous Sensibility. Critical Review. Brain, LXV, 48, 1942.

THE TREATMENT OF DIFFICULT AND UNUSUAL NON-UNIONS

With Special Reference to the Bridging of Defects *

BY HAROLD B. BOYD, M.D., MEMPHIS, TENNESSEE

From the Willis C. Campbell Clinic, Memphis

In this paper, the management of unusual non-unions is considered. Reference is made to the treatment of congenital pseudarthrosis with the dual bone graft, followed by a discussion of the treatment of non-unions near joints and the bridging of bone defects, including those secondary to gunshot wounds and compound fractures with sequestration.

The difficulty in securing bony union in congenital pseudarthrosis and a method of treating this condition with dual bone grafts has been discussed previously.[1] Since this report, an additional patient with congenital pseudarthrosis (Case 1, J. E., No. 41224) has been treated by a dual bone graft with a good result (Figs. 1-A, 1-B, and 1-C). It is interesting to note that, in the first seven months following the operation, the affected tibia grew one and one-tenth centimeters more than the unaffected tibia. This excess of growth is probably due to an operative stimulation of the epiphyseal lines.

It is the consensus that, of all non-unions, bony union is most difficult to secure in congenital pseudarthrosis. After obtaining bony union in these cases with the dual bone graft, it was decided that this method should be tried in the more difficult non-unions, especially those occurring near joints.

Dr. Campbell first reported his method of treating non-unions with the onlay graft in 1924. His last paper discussing onlay bone grafts for ununited fractures, in which autogenous bone pegs were used, was published in 1939. In recent years the operation has been modified, and now metallic screws are used in place of the autogenous bone pegs.[4] The onlay graft has now been used by the Clinic staff in the treatment of 511 non-unions with gratifying end results. As previously reported, bony union has been obtained in between 93 and 94 per cent. of the cases.[3, 4] The single onlay bone graft is still used at the Clinic in the majority of non-unions, but in unusual cases it may not be applicable. It is the purpose of this paper to discuss these exceptional cases. In a number of these non-unions, fibular transplants or dual bone grafts have been employed.

USE OF THE DUAL GRAFT IN NON-UNIONS NEAR JOINTS

Non-unions near joints are hard surgical problems. The frag-

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 19, 1943.

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FIG. 1-A

Case 1. J. E. (No. 41224). Typical congenital pseudarthrosis in a child aged five years.

FIG. 1-B

Appearance of the bone immediately following the application of the dual bone graft. Note the proximity of the grafts to the lower epiphyseal line.

ment nearest the joint is short, making it difficult to obtain secure mechanical fixation of the graft to the fragment. This difficulty is increased by the osteoporosis usually present in the short fragment. The major portion of the bone in the fragment near the joint is cancellous, with a thin cortex. These elements all jeopardize the fixation of the graft to the fragment adjacent to a joint. Oftentimes it is impossible to obtain fixation with a single graft; screw threads will not hold well in the soft bone, and wire sutures tend to cut through the bone.

With the dual graft, a forceps-like action may be obtained, and the screw threads hold in the cortical bone of the two grafts. The soft cancellous bone is compressed between the ends of the grafts. This is well illustrated in Case 3. See Figures 3-A and 3-B.

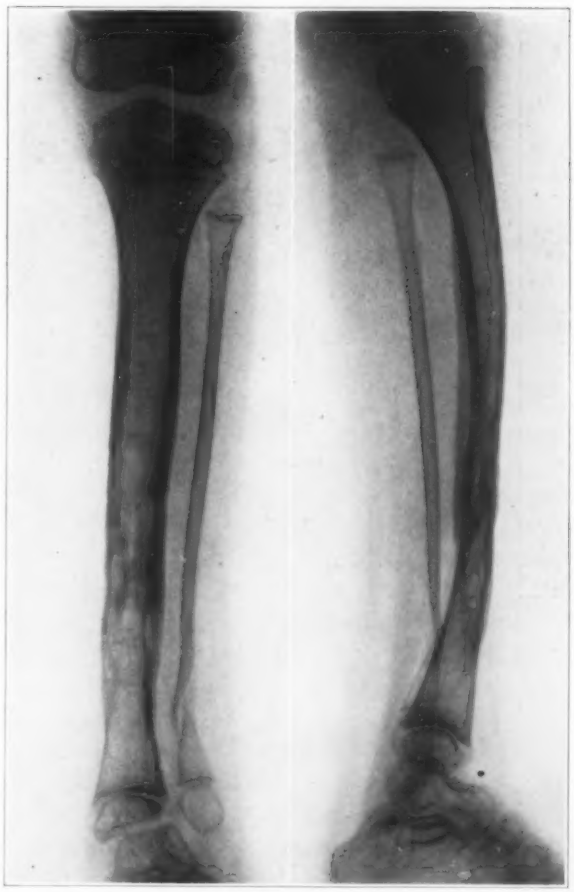

FIG. 1-C

Condition of the bone fifteen months following the application of the grafts. Note the distance between the grafts and the lower epiphyseal line. As measured by teleoroentgenograms, the affected tibia grew one and one-tenths centimeters more than the unaffected tibia in the first seven months after operation. This is probably due to operative stimulation of the epiphyseal lines.

Case 2 (L. F., No. 47343) illustrates a severe non-union of the humerus near the shoulder. This followed a compound fracture of the humerus with sequestration of a portion of the shaft (Fig. 2-A). A dual bone graft was employed eleven months following the injury. Figure 2-B shows the appearance of the grafted humerus six weeks following the operation. This illustrates the "bone clamp" action of the dual graft; also the holding power of the screws through the two grafts. The screws would probably not have held in the osteoporotic proximal fragment if only one graft had been used. A postoperative infection developed in this patient, probably due to relighting the old infection which followed

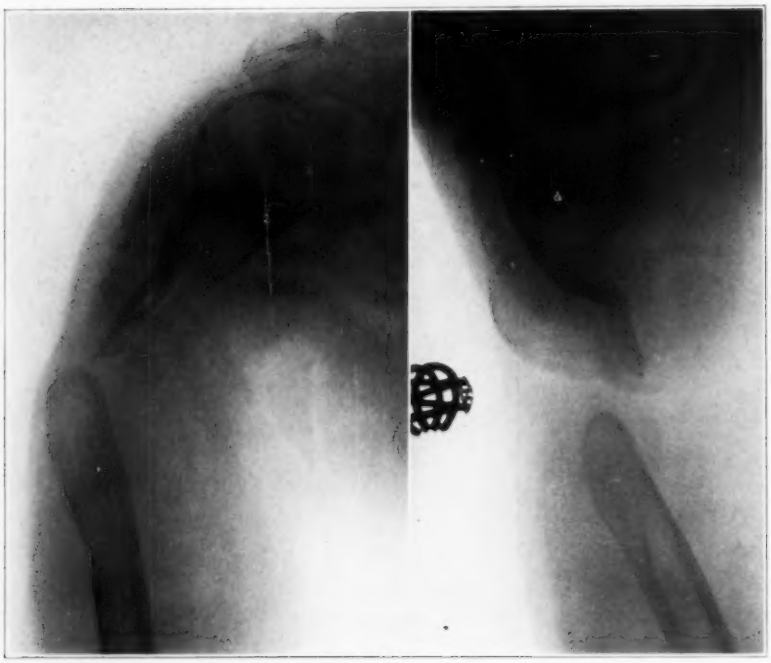

FIG. 2-A

Case 2. L. F. (No. 47343). A large defect is illustrated in the upper third of the humerus, which followed a compound fracture with sequestration.

the compound fracture. There was partial sequestration of one graft. The wound healed after six months, and seventeen months after the operation there was solid bony union with no drainage (Fig. 2-C). At this time the patient had approximately 50 per cent. of the normal range of motion in the shoulder, and the function was gradually improving.

Case 3 (W. D. S., No. 50450) was a case of non-union following a compound Colles' fracture which had been treated elsewhere by débridement and a wire loop for internal fixation (Fig. 3-A). A dual-graft operation was performed five months following the accident. Roentgenograms taken nine months after the operation (Fig. 3-B) reveal solid bony union. The forceps-like action of the grafts on the distal fragment is well illustrated in this case.

USE OF THE DUAL GRAFT IN NON-UNION OF A SINGLE FOREARM BONE

When non-union occurs in one of the bones of the forearm without shortening of the other, grafting is often difficult without shortening both bones. After the ends of the fragments are freshened and the eburnated bone is excised, a space results which cannot be closed, because of the splinting by the normal bone. The bridging of such a defect with a single onlay graft may result in union, but the chances of success are minimized even when the space is filled with cancellous bone, as the latter

is compressed by the contracting soft tissue during healing. When union occurs, a hemi-hourglass constriction may result, in which refracture is likely to occur. If a defect of this kind is bridged by a dual graft and the space is filled with cancellous bone, the chances for union are increased. The necessity for shortening the normal bone, or resecting the head of the radius, as is occasionally done in non-union of the ulna, is avoided. Case 4 illustrates this point.

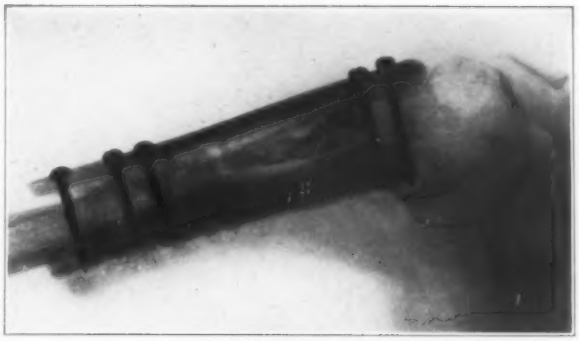

FIG. 2-B

Appearance of the bone six weeks following application of dual bone graft. This illustrates the clamplike action of the dual graft, and its holding power on the osteoporotic proximal fragment.

FIG. 2-C

Appearance of the bone seventeen months after operation. Solid bony union has occurred despite postoperative infection. (See text.)

CASE 4 (L. P. F., Jr., No. 32959). This was a compound fracture of the ulna with dislocation of the head of the radius. A fascial loop had been placed around the neck of the radius as a substitute for the annular ligament. A non-union of the ulna with angulation had resulted. The tendency to redislocation of the head of the radius exerted pressure on the fascial loop, and caused an erosion of the neck of the radius (Fig. 4-A). Eleven months after the fracture, the pseudarthrosis was excised, along with a portion of the eburnated bone about it. A dual graft was applied and the defect was filled with cancellous bone. Union, with sufficient function in the forearm to allow the patient to work, was present in three months. Figure 4-B shows the result ten months following the application of the graft. At this time the patient was carrying out his duties as a structural steel worker. There was motion in the elbow from normal flexion to 165 degrees of extension. Supination was 75 per cent. of normal, and pronation was 50 per cent. of normal as compared with the opposite side.

USE OF THE DUAL BONE GRAFT IN DIFFICULT NON-UNIONS IN THE SHAFTS OF LONG BONES

In severe non-unions in the shafts of long bones, where one is fearful

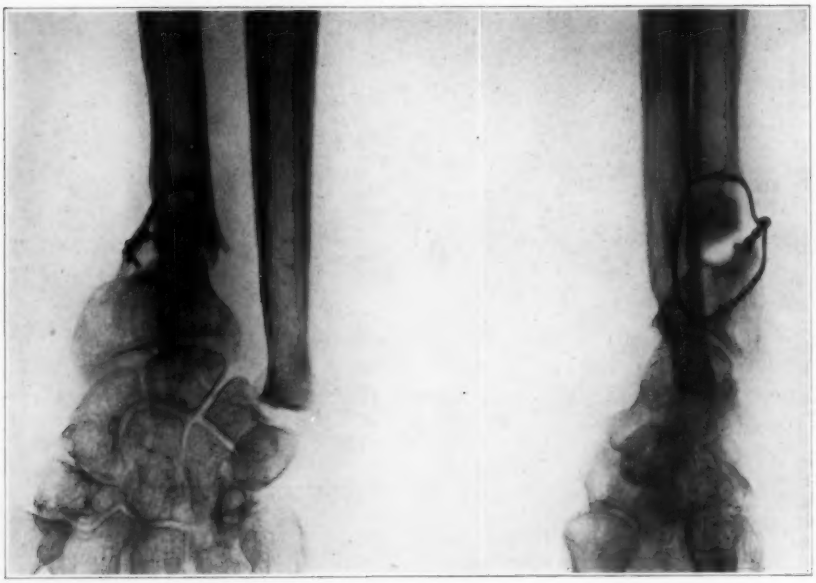

FIG. 3-A

Case 3. W. D. S. (No. 50450). Non-union of the radius, as first seen at the Clinic, sixteen months following a compound fracture which had been treated by open reduction and internal fixation.

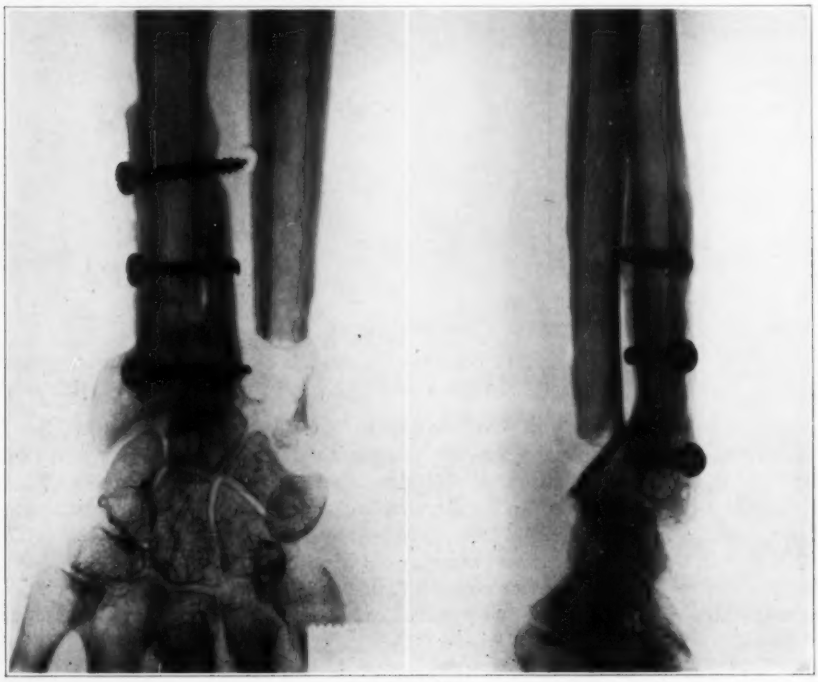

FIG. 3-B

Appearance of the radius nine months following application of dual bone grafts. This illustrates the forceps-like action of the dual graft on the small osteoporotic distal fragment.

FIG. 4-A

Case 4. L. P. F., Jr. (No. 32959). Non-union of the ulna following Monteggia fracture.

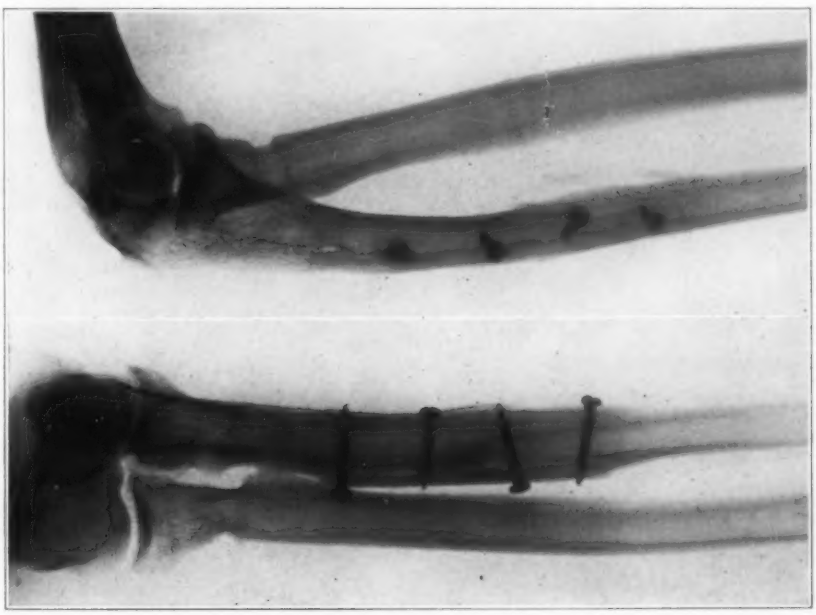

FIG. 4-B

Appearance of the bone ten months following application of the dual bone graft. Solid bony union is present. The defect in the ulna has been spanned without shortening the radius.

FIG. 5-A

Case 5. W. G. H. (No. 52964). Non-union of the femur, of two years' duration, followed a compound fracture and sequestration.

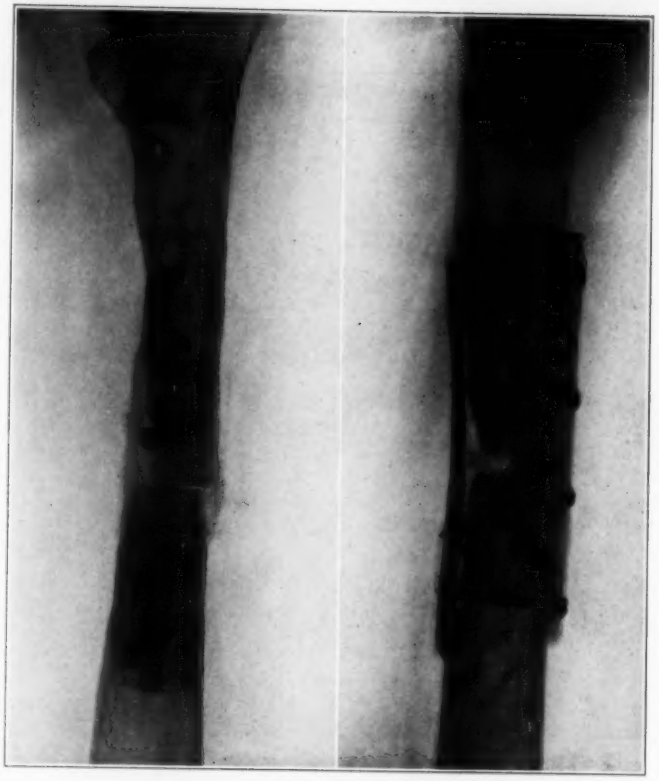

FIG. 5-B

Condition of the bone four months following application of dual bone graft. It is too early to state whether a solid bony union will occur; however, the wound healed without infection and the patient is walking in a brace.

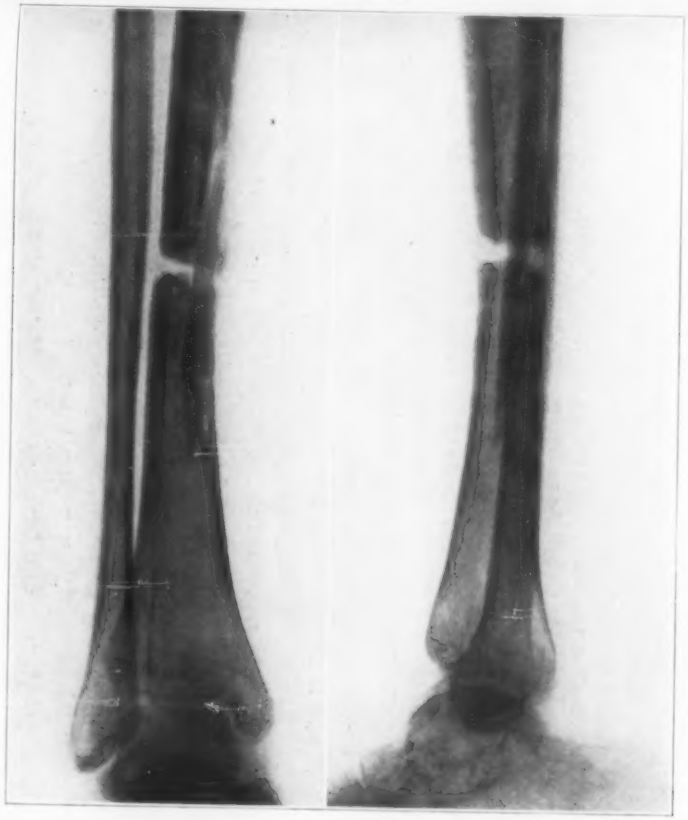

FIG. 6-A

Case 6. MRS. R. D. (No. 55194). A defect in the tibia is illustrated, which developed after osteotomy and persisted following a sliding bone graft.

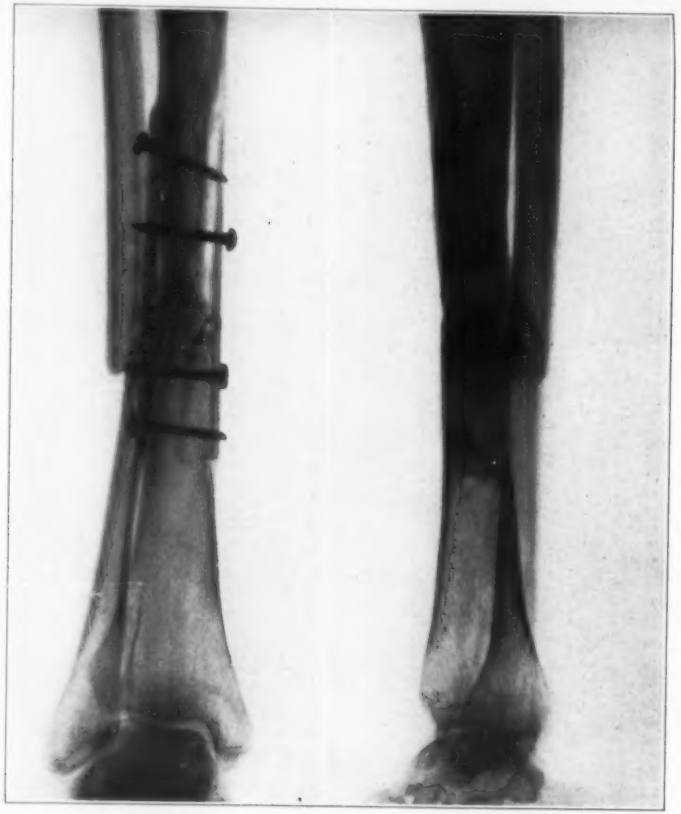

FIG. 6-B

Bony union is shown seven months following application of the dual bone graft.

of failure following a single onlay bone graft, the additional advantages of the dual graft may increase the chances of union. This is illustrated in the treatment of a patient with a non-union of the femur (Case 5).

CASE 5 (W. G. H., No. 52964). This patient was first seen at the Clinic one year following a severe compound, comminuted fracture of the femur. At this time drainage was still present. A sequestrectomy was performed fourteen months following the injury. Drainage continued and, nineteen months following the accident, a second sequestrum was removed. Four weeks following this operation, the wound healed, and for the first time there was no drainage. After the wound had remained healed for five months (two years and one month following the fracture), a dual-bone-graft operation was performed and sulfanilamide crystals were placed in the wound. Figure 5-A shows the appearance of the bone just before the bone graft. The wound healed without infection. Figure 5-B shows the condition of the bone four months following the dual bone graft. At the present time the patient is walking in a brace. The shortening in the affected extremity is two and one-half inches.

A non-union of the tibia, which followed an osteotomy and persisted after a sliding bone graft, is illustrated by Case 6.

CASE 6 (Mrs. R. D., No. 55194). Before admission to the Clinic, the patient had had a rotation osteotomy of the tibia for a cavus deformity of the foot. This had been followed by a non-union. An operation using a sliding bone graft had been done four months after the osteotomy. There had been no union following this bone graft. Figure 6-A shows the condition of the tibia when the patient was first seen at the Clinic; this was six months after the bone graft. The lower extremity had been immobilized in casts since the sliding bone graft had been inserted. Examination, after removal of the cast, revealed a non-union of the tibia. There was no clinical or roentgenographic evidence of any attempt at union. Free motion was present at the fracture and no callus was visible in the roentgenograms. There was absorption of bone about the fracture site and partial atrophy of the sliding graft.

A dual-graft operation was done, and the space about the pseudoarthrosis was filled with cancellous bone. Figure 6-B shows the appearance of the graft seven months following the dual graft. At this time the fracture was clinically solid, and the long leg brace in which she had been walking for three months was converted into a short leg brace. The brace was discarded one month later. For the past three months she has been walking without support and carrying on her normal activities as a housewife.

TECHNIQUE OF THE DUAL BONE GRAFT

After exposure of the pseudarthrosis through a suitable incision, the fibrous tissue about the non-union and between the bone fragments is excised. The ends of the fragments are freshened and, if not contraindicated, the sclerotic bone about the ends of the fragments is excised back to normal or approximately normal osseous tissue. The medullary canal in each fragment is thoroughly opened with a drill or curette, to aid in the restoration of the blood supply through the medullary canal and the formation of callus. Occasionally one does not wish to mobilize the fragments sufficiently to open the medullary canal.

The pseudarthrosis is then reduced and the fragments are aligned in the optimal position. The best locations for the grafts are selected. The sides of the fragments are then denuded and flattened in the areas to receive the grafts by elevating bone chips with a sharp osteotome.

Only sufficient bone is removed from the fragments to insure reasonably flat surfaces for the grafts. No effort is made to countersink the grafts into the shaft of the grafted bone. On the other hand, sufficient bone must be removed to secure denuded flat surfaces to receive the grafts.

Meanwhile, a second operative team removes a long graft from the anteromedial surface of the tibia. The best graft is secured if the borders of the tibia are not disturbed. This method results in a minimal weakening of the bone, as the tibia is reinforced at its borders. The periosteum is not removed with the graft, as it has not been proved that leaving the periosteum on the graft is of any material benefit. The preservation of this membrane at the site of the removal of the graft is of definite value, as the sutured periosteum forms a barrier which inhibits an irregular growth of bone at the site of the removal of the graft. It also probably aids in the reformation of bone to fill the defect formed by the removal of the graft.

The cancellous portion of the graft is separated from the cortical portion with a motor saw. Two cortical grafts are obtained by dividing the graft at its center. Additional endosteum is removed from the upper end of the tibia with a curette.

The cortical grafts are placed in the prepared beds, one on each side of the fracture site, and are held in position by means of metallic screws which pass through both grafts and the intervening grafted bone. Occasionally the operative procedure is made easier by temporarily fixing one graft in position with short screws. The second graft is then placed in position and screws are passed through both grafts and the intervening bone. The temporary screws are then removed from the first graft and replaced by permanent screws which pass through both grafts and the intervening bone. This method has been previously described.[1]

The cancellous bone, which was removed from the upper end of the tibia and from the medullary side of the cortical graft, is packed about the fracture site. The space between the dual grafts on both sides of the pseudarthrosis should be carefully filled with cancellous bone. This is an important step in the procedure, as cancellous bone promotes the formation of callus faster than any other type of transplant.

If sulfanilamide is to be placed in the wound, it is well to roll the bits of cancellous bone in a basin containing the crystals. This gives a uniform coating of the drug over the small endosteal transplants, and ensures an even distribution of the drug about the fracture site.

If the pseudarthrosis has been formerly infected, sulfanilamide crystals are routinely placed in the wound. If there has been no previous infection, sulfanilamide crystals may or may not be placed in the wound, at the discretion of the surgeon. The wound is closed in the usual manner and a suitable plaster-of-Paris cast or other external fixation is applied.

The advantages of the dual graft are:

1. Better mechanical fixation is obtained than with the conventional types of bone-grafting.

2. The cancellous bone about the fracture is revascularized quickly, producing a strong osteogenic element.

3. The tibial grafts are revascularized slowly, providing rigid internal fixation over a long period of time.

4. With a single graft, the screws may fail to hold in osteoporotic bone. The dual graft forms a bone clamp and compresses the fragments between the grafts.

5. Where one of the fragments is short, the dual grafts can be made to act as a forceps to hold this fragment.

6. The grafts form a trough into which the cancellous bone is packed about the fracture.

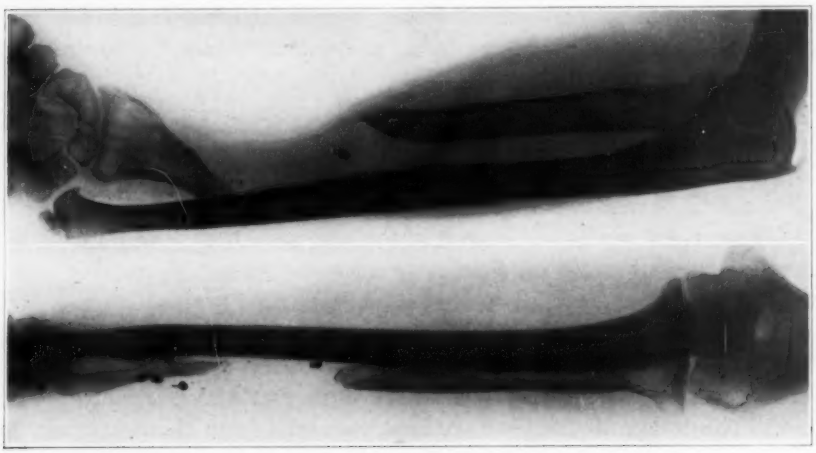

FIG. 7-A

Case 7. E. S. (No. 48724). This large radial defect resulted from a shotgun wound.

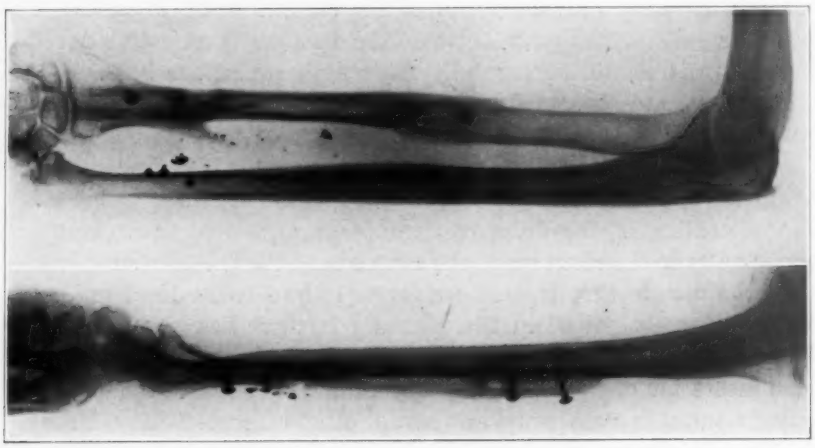

FIG. 7-B

The defect has been spanned with a fibular graft. Roentgenograms illustrate bony union ten months following the operation.

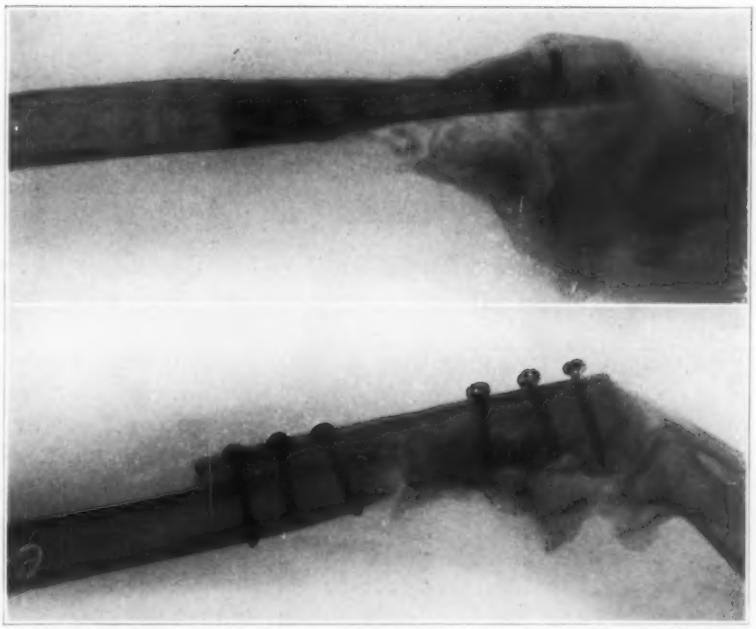

FIG. 8-B

Roentgenograms taken two months following the bridging of the defect with a whole fibular transplant.

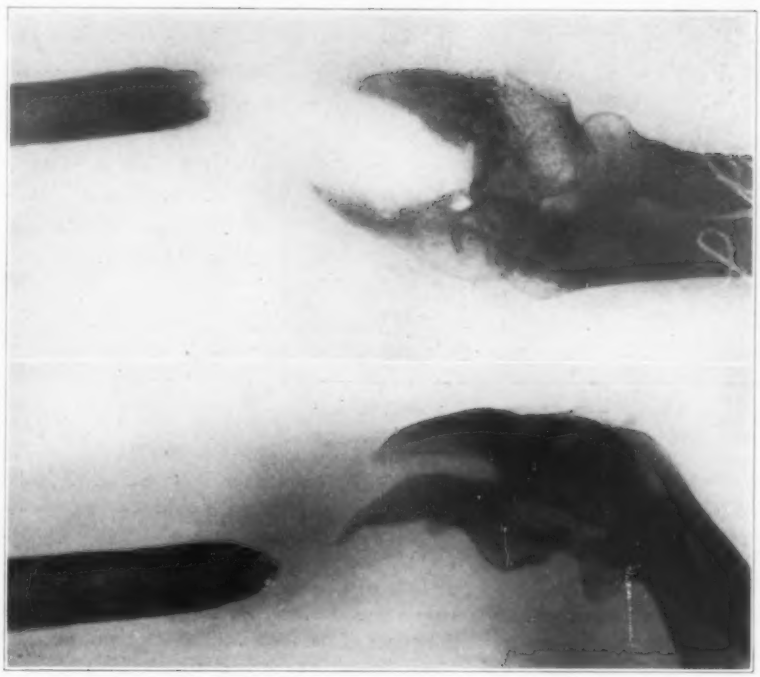

FIG. 8-A

Case 8. A. L. R. (No. 44587). Illustrates a large defect in the lower third of the humerus following a compound fracture.

7. During the healing process, the grafts prevent compression of the transplanted cancellous bone by contracting fibrous tissue, thus minimizing the hemi-hourglass constriction occasionally seen when a bone defect is bridged by a single graft.

8. The diameter of the grafted bone is increased.

9. Partial absorption of one graft does not necessarily result in failure, as the second graft maintains the internal fixation.

BRIDGING OF BONE DEFECTS WITH FIBULAR GRAFTS

In some cases the fibula provides an ideal graft. Its tubular structure makes it stronger than a tibial graft of similar size. This additional strength is useful in filling defects, and often the soft tissue can be closed over it when it would be impossible to close the wound over a dual graft. The fibula is more suited to the filling of long defects than is the dual graft. This is especially true in the bones of the upper extremity, as they are smaller than the bones of the lower extremity and are not subjected to the strain of weight-bearing. Cases 7 and 8 illustrate the use of fibular grafts.

FIG. 8-C

Solid bony union is illustrated one year and eight months following the fibular transplant.

CASE 7 (E. S., No. 48724). A large defect in the radius resulted from a shotgun wound one year before admission. Figure 7-A shows the extent of the bone defect and also the soft-tissue deficiency of the lower third of the forearm, the radial shortening and the radial deviation of the hand. Flexion and extension of the fingers were diminished to about 25 per cent. of normal by the damage to, and laxity of, the forearm muscles. When the radial shortening had been partially overcome by traction, the function of the fingers was greatly increased. The defect was filled by a long fibular graft. The gap proper was filled with the entire circumference of the fibula. The graft was notched at each end by removing approximately half the circumference of the fibula. Exact measurements were made before the fibular graft was notched so that it would fill

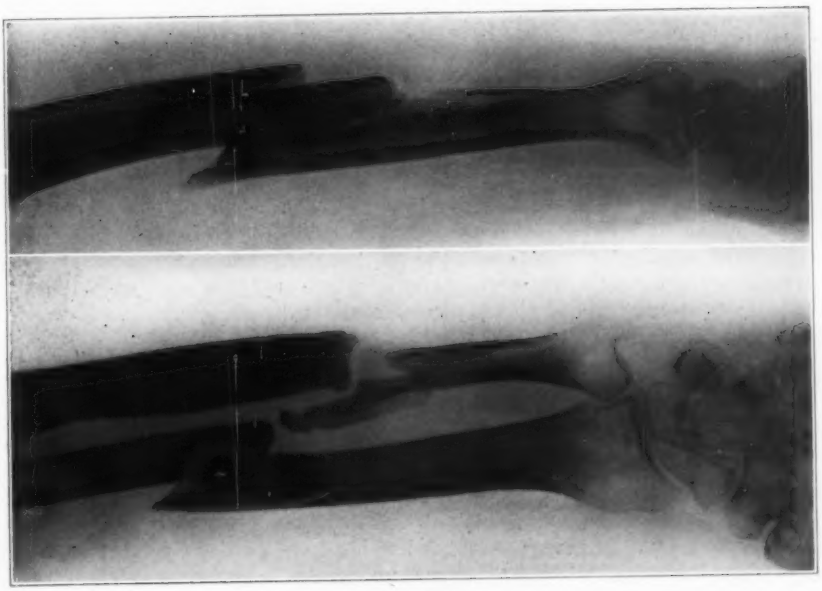

FIG. 9-A

Case 9. W. E. N. (No. 53334). Overlapping and non-union of the radius associated with a defect in the ulna.

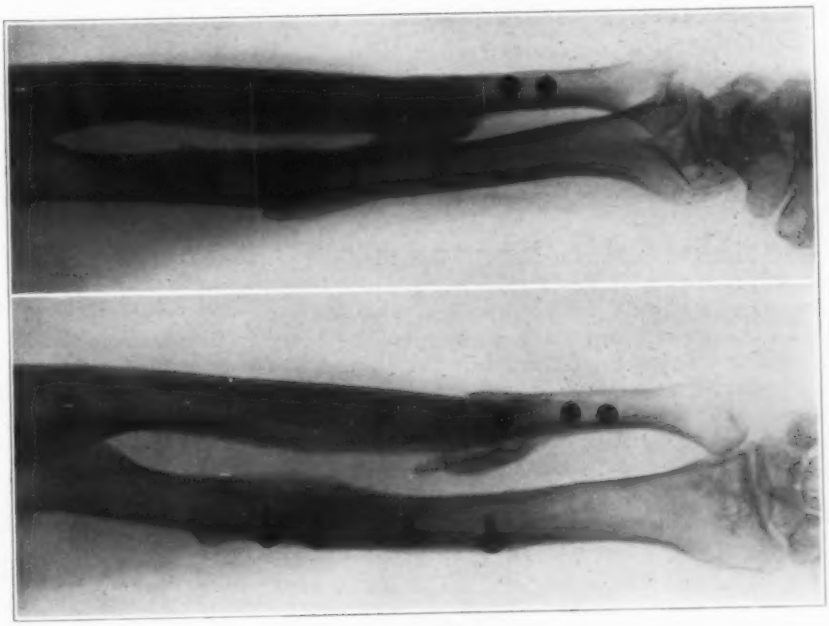

FIG. 9-B

Result eight and one-half months following single onlay bone grafts of the radius and ulna, at which time the defect in the ulna was filled by the overlapping portion of the radius. (See text.)

the gap when maximum radial length was obtained by traction on the hand. The notched portion of the graft was then used as an intermedullary graft in the lower radial fragment, and was held by one screw through the lower fragment of the radius and its inserted fibular graft. The proximal notched end of the fibular graft was applied to the proximal radial fragment as an onlay graft and was held by two screws. Figure 7-B shows the result ten months following the operation. At this time there was clinical and roentgenographic union of the fibular transplant to the radius. The patient had a normal range of motion in the elbow joint. The wrist was in good functioning position and the motion in this joint was 25 per cent. of normal. Pronation and supination were 50 per cent. of normal. The flexion and extension of the fingers were 80 per cent. of normal, and the patient was able to appose the thumb to all of the fingers. At this time the patient was carrying out his ordinary activities as a farm hand.

Case 8 illustrates the bridging of a bone defect in the humerus with a fibular transplant.

Case 8 (A. L. R., No. 44587). This patient had suffered a compound fracture of the humerus with subsequent loss of bone. Figure 8-A shows the defect present on arrival at the Clinic eleven months after the accident. Figure 8-B shows the appearance of the humerus two months after the defect had been bridged with a fibular graft. The internal condyle of the humerus was osteotomized, and the upper portion of the condyle and adjacent bone were slipped lateralward to close the space between the condyle and the graft. The heads of the two lower screws were palpable under the skin. They were removed under local anaesthesia nine months after the operation. Figure 8-C shows the result one year and eight months after the insertion of the graft. At this time the patient had normal function in the left upper extremity, except for ankylosis of the elbow which was present before the operation. It was originally planned to follow the graft by an arthroplasty of the elbow; however, this patient was fond of playing golf, and was able to shoot in the seventies. He felt that the stiff left elbow was no handicap in this game, and might be an advantage. This was an element in his refusal to have an arthroplasty.

TREATMENT OF NON-UNION OF BOTH BONES OF THE FOREARM, WITH A DEFECT IN A SINGLE BONE

In non-union of both bones of the forearm with overlapping of one bone and a defect in the other, the following method of treatment may be used:

Case 9 (W. E. N., No. 53334). Operation was performed one year following an extensive compound, comminuted fracture of both bones of the forearm. A defect was present in the ulna, with an overlapping of the radius (Fig. 9-A). After the sites of non-union were exposed, the maximum length of the forearm which could be secured by reasonable traction was determined. The fragments of the overlapping radius were cut with a saw to permit end-to-end apposition. The excess portion of the overlapping radius was used to fill the defect in the ulna. Care was taken to cut the section of radius to fit the gap in the ulna properly, after the ends of the ulna had been resected to receive the transplant. Both fractures sites were then bridged by an onlay cortical graft from the tibia, and cancellous bone was packed about the fracture sites. Figure 9-B illustrates the condition of the bones eight and one-half months following the bone graft. The patient was able to return to work while wearing a leather lacer brace three months following the operation. Five months following the operation the leather lacer brace was discarded, and since that time the patient has been working at his regular occupation as an operator of a bulldozer. The fractures are clinically solid. The external contour of the arm is good. The patient has about 75 per cent. of normal flexion in the wrist. He has a normal range of motion in the fingers, and good gripping power. Apposition of the thumb is normal. There is motion in the left elbow from 55 to 160 degrees.

Roentgenograms reveal that the onlay bone grafts have united to the shafts of the radius and ulna, that two of the fracture sites have healed, and that the third is filling in satisfactorily.

If the whole forearm had been shortened to the length of the ulna without filling the gap, the relaxation of the soft parts would have been sufficient to prevent good action of the forearm muscles.

The method has the disadvantage that three fracture sites require union instead of the usual two. It also has the drawback of an additional free transplant filling the gap. Such a transplant would fare badly in the presence of an infection. Fortunately, in this patient the postoperative wound healed without infection.

RESULTS

The procedures described in this paper have been used by the members of the Clinic staff on twenty-two patients. Eighteen of these were dual grafts. In this series there has been one failure. One patient the Clinic was unable to trace, and three have been operated upon too recently to determine the end result. Two of these appear favorable as no postoperative infection developed in either, and the grafts give evidence of uniting satisfactorily. In the third patient a dual bone graft was used to bridge a defect in the tibia, following a severe compound fracture of twenty-three months' duration. There was intermittent drainage for eighteen months following the injury, with sequestration. The old infection was relighted at the time of operation. Clinically the fracture is united three and one-half months after the operation. Roentgenographically the defect is slowly filling in. The drainage is gradually subsiding, but there is still a small draining sinus.

The failure was in a patient with an extensive non-union near the elbow joint. There was a marked limitation of motion in the joint before operation. A dual-graft was performed, and following the operation, an attempt was made to preserve the partial motion in the elbow by physiotherapy. This form of treatment was carried out before bony union had occurred. A failure of the dual graft resulted. In non-unions near joints, active and passive motion in the joint should be delayed until union is obtained, or carried out with extreme care after one is reasonably sure that union is taking place.

COMMENTS AND CONCLUSIONS

The treatment of non-union following fractures has always been a difficult surgical problem. If the non-union follows a compound fracture, the problem becomes more complicated because of the increased risk of a postoperative infection. Experience has demonstrated that, with the proper use of chemotherapy, especially its local use in wounds, the number and severity of postoperative infections can be decreased. With this aid, severe non-unions following compound fractures can be bone-grafted with greater chances of success than formerly.

The experience in this Clinic and the published reports of Henderson, Campbell, and Speed have convinced the writer that the majority of non-unions are best treated by the onlay bone graft as recommended by these authors. If the non-union presents unusual difficulties, such as congenital pseudarthrosis, non-unions near joints, poor quality of bone because of previous infection or osteoporosis, or failures following ordinary methods of bone-grafting, the single graft may not be sufficient. Under such conditions the surgeon may be wise to use the dual graft, as the chances for union are greater.

Where large defects are present in the bones of the lower extremity, it is probably best to shorten the extremity sufficiently to employ a single or a dual onlay graft. Large defects in bones of the upper extremity can often be bridged with fibular grafts. This is especially true where the defect involves one of the bones of the forearm.

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BONE CHANGES IN ACUTE AND CHRONIC SCURVY

An Experimental Study*†

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Experimental scurvy had its beginning in 1907 when Holst and Frölich introduced the guinea pig as a suitable and inexpensive laboratory animal. Their description of the microscopic bone changes in guinea pigs dying in acute scorbutus remains a classic in the literature. These changes have been shown to be fundamentally the same in clinical cases of acute vitamin-C deficiency. A knowledge of the changes in bone during acute scorbutus is necessary in order to compare and interpret the alterations in chronic or protracted scurvy with which this paper primarily deals.

ACUTE SCURVY

In acute scurvy, the formation of bone and cartilage ceases at the epiphyseal plate, and longitudinal growth, therefore, no longer occurs. This is in accord with the experiments of Wolbach and Howe who demonstrated that in guinea pigs with absolute scurvy intercellular substances, such as bone and cartilage, can neither be made nor maintained. Bone absorption, on the other hand, proceeds at an accelerated rate. This is most marked in the metaphysis, although all portions of the bone undergo osteoporosis with progressive fragility of the entire skeleton. The atrophy at the ends of the shaft is usually of such a high degree that the epiphysis is held in place by a cuff of thickened periosteum. This accounts for the ease and frequency of epiphyseal displacements (Fig. 1), which may occur through the zone of calcified cartilage columns without damage to the plate. Premature closure of the disc with the arrest of growth, therefore, is not a sequel of clinical cases of acute scurvy.

The framework of bone trabeculae disappears rapidly from the metaphysis. Cartilage columns become fragmented and undergo irregular absorption (Fig. 2-A). The hemopoietic marrow is replaced by a characteristic loose, oedematous-appearing, fibrous or "scurvy" marrow, containing spindle-shaped and stellate fibroblasts (Figs. 2-C and 2-D). Cells which appear to be osteoblasts revert back to fibroblasts, so that in the late stages of acute scurvy it is difficult to demonstrate them in the regions of bone formation. The epiphyseal cartilage plate becomes decreased in width, chiefly by the loss of its calcified zone, and wavy in appearance, and its cells and columns become irregular in outline. Fractures and hemorrhages, old and recent, complete the histological picture.

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†This paper was presented before the Chicago Orthopaedic Society in May, 1942.

CHRONIC SCURVY

Since the isolation and synthesis of cevitamic acid in 1932, and the accumulation of accurate clinical and laboratory data, the author's attention has been focused on the possible existence of a protracted or chronic form of scurvy. While complete evidence is still lacking in the case of humans, guinea pigs can be maintained for as long as four months or more on a subnormal ration of ascorbic acid, producing a protracted form of the deficiency. The bone changes under these circumstances, as reported by Ham and Elliott, differ materially from not only the changes in guinea pigs with acute scurvy, but also from the findings in nineteen cases of chronic scurvy in humans, as reported by Park, Guild, Jackson, and Bond.

Ham and Elliott concluded that, in chronic scurvy, guinea pigs maintained the ability to form bone and cartilage at the epiphyseal plate, and that longitudinal growth continued, although at a reduced rate. They postulated that in the absence of adequate growth energy—namely, vitamin C—the cartilaginous disc grew only about its peripheral portion. Since marginal bone formation would result in added length, growth activity is reduced or completely eliminated from the central portion of the disc where the continued formation of trabeculae of bone would afford additional strength for the metaphysis, but would not be essential for growth in length. The illustration in their article suggests a totally inactive growth disc. If the shaft is actually increased in length by the addition of bone at the junction of the cortex and cartilaginous disc, it would appear desirable to demonstrate this growth by an established method.

EXPERIMENTAL STUDIES

The following experiments were undertaken in an effort to study the histopathological changes in chronic scorbutus.

Methods and Material

Guinea pigs weighing 250 to 350 grams each were used in three groups of experiments as follows:

Experiments	No. of Animals
A. Study of bone changes in varying degrees of vitamin-C deficiency	50
B. Correlation of longitudinal growth, as determined by serial roentgenograms, and the microscopic appearance of the epiphyseal disc	35
C. Biopsy of the proximal tibial epiphysis after thirty days, and the determination of the presence of longitudinal growth by the India-ink method in the opposite tibia during the twenty-five days preceding the death of the animal	65
	150

The animals were divided into groups of four or more pigs and placed in cages sufficiently large to permit free activity. Eddy's modification of the Sherman-La Mar diet was used as the basic food. This was

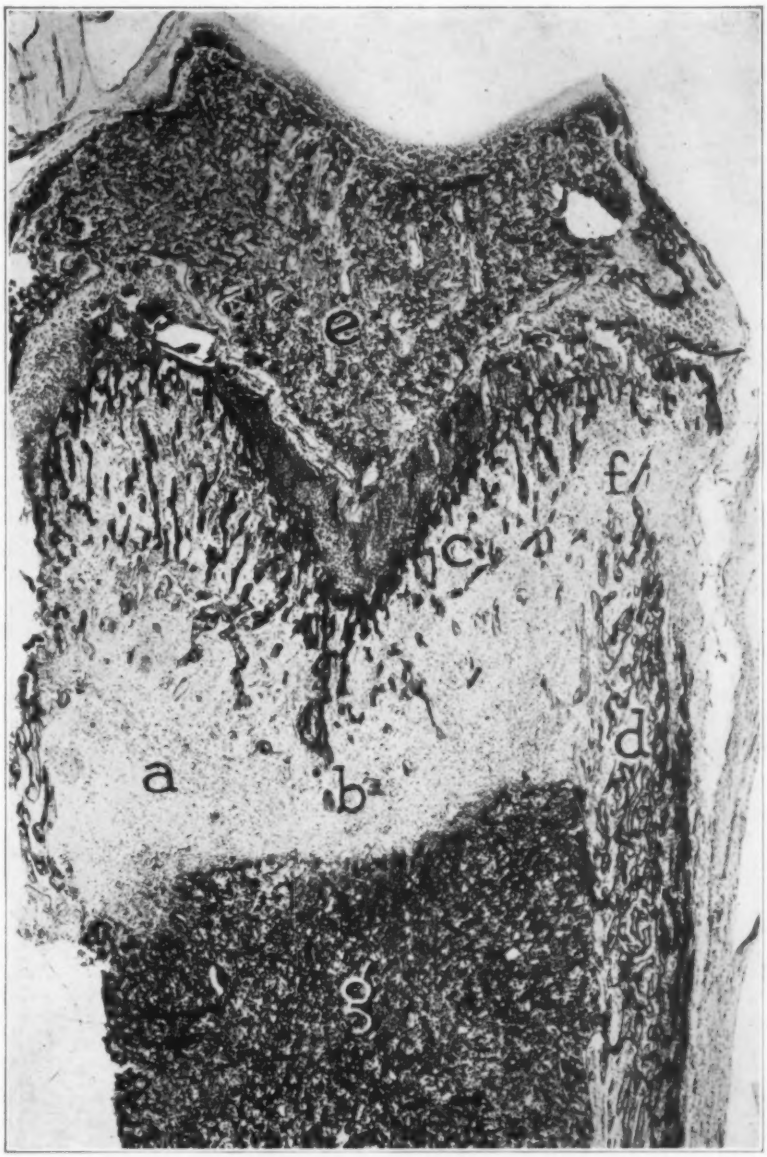

FIG. 1

Photomicrograph showing characteristic lesion of acute scurvy at the distal end of the femur of a guinea pig dying after twenty-five days on the basic diet. Note the fibrous replacement of marrow (*a*), the few remaining bone trabeculae (*b*), fragmentation and absorption of calcified columns (*c*), atrophy of cortex (*d*), displacement of the epiphysis (*e*) at (*f*), and the unchanged hemopoietic marrow (*g*). The left cortex is missing from the section.

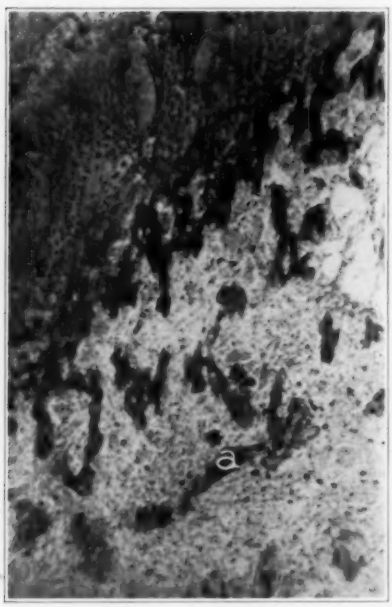

FIG. 2-A

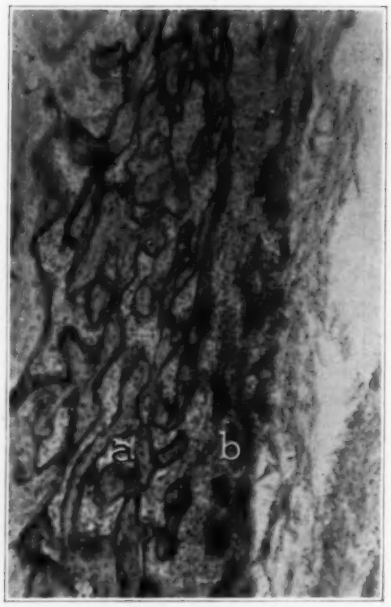

FIG. 2-B

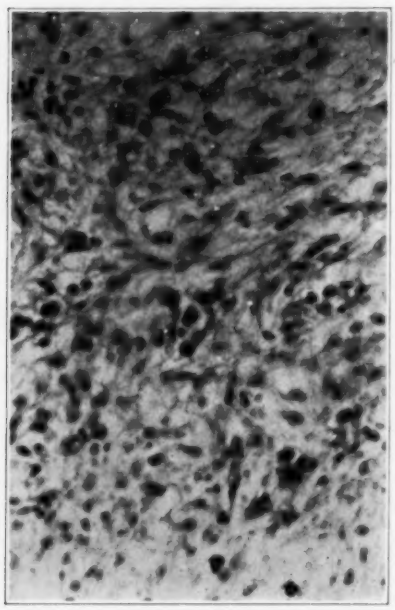

FIG. 2-C

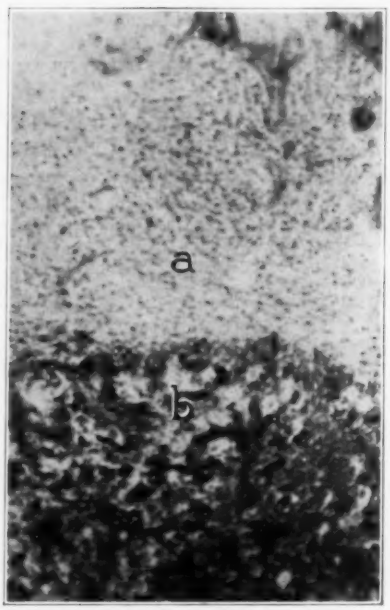

FIG. 2-D

Photomicrographs showing high-power detail of areas in Fig. 1.

Fig. 2-A: Juxta-epiphyseal region with fragmentary remains of calcified columns, one of which (*a*) lies transversely to the long axis of the shaft.

Fig. 2-B: Note the extreme atrophy of the shaft (*a*), and the subperiosteal new bone (*b*).

Fig. 2-C: Typical *Gerüstmark* or loosely textured scurvy marrow.

Fig. 2-D: Abrupt transition between fibrous (*a*) and hemopoietic marrow (*b*).

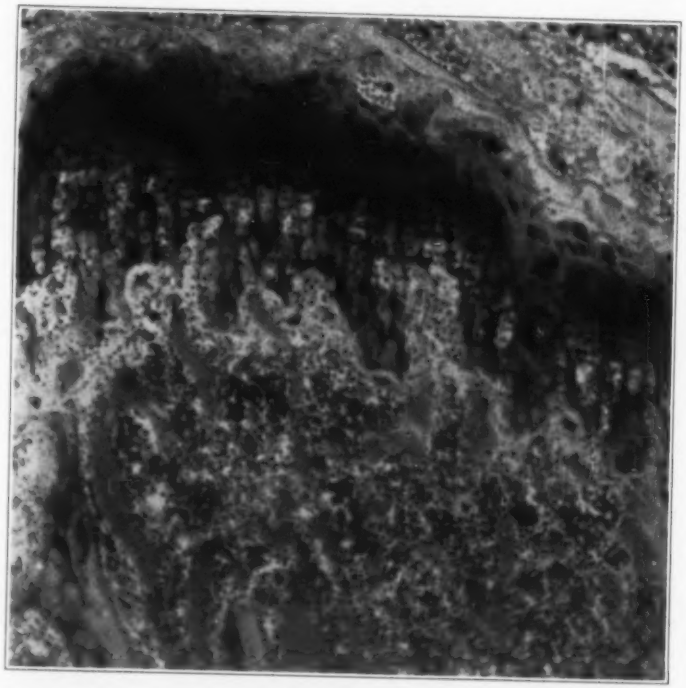

FIG. 3-A

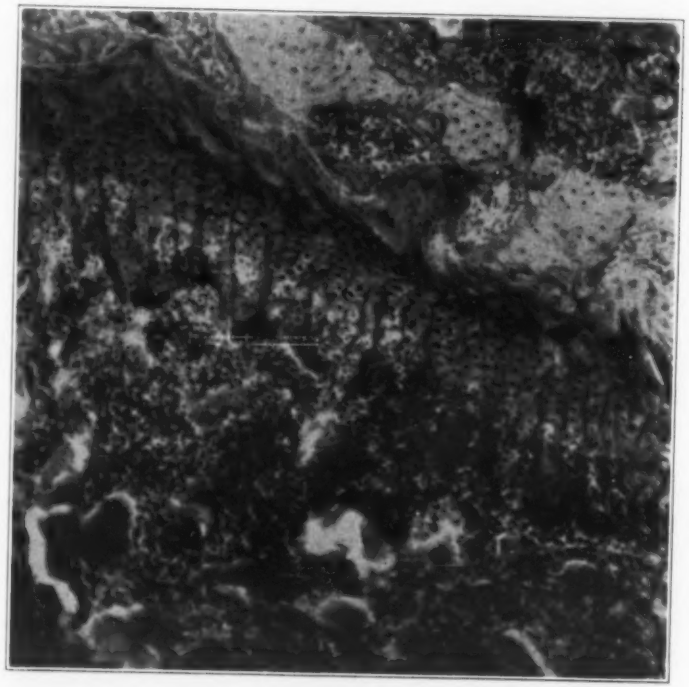

FIG. 3-B

Fig. 3-A: Photomicrograph of portion of the epiphyseal disc of a guinea pig which had received the basic diet and one and one-half cubic centimeters of lemon juice for eighty-six days. Note the diminution in growth activity as compared to the control pig (Fig. 3-C). Although the cartilage plate and columns are narrowed, enchondral ossification is proceeding in a normal manner.

Fig. 3-B: Photomicrograph of growth plate from pig which had received one cubic centimeter of lemon juice for seventy-eight days shows less growth activity than is indicated in Fig. 3-A.

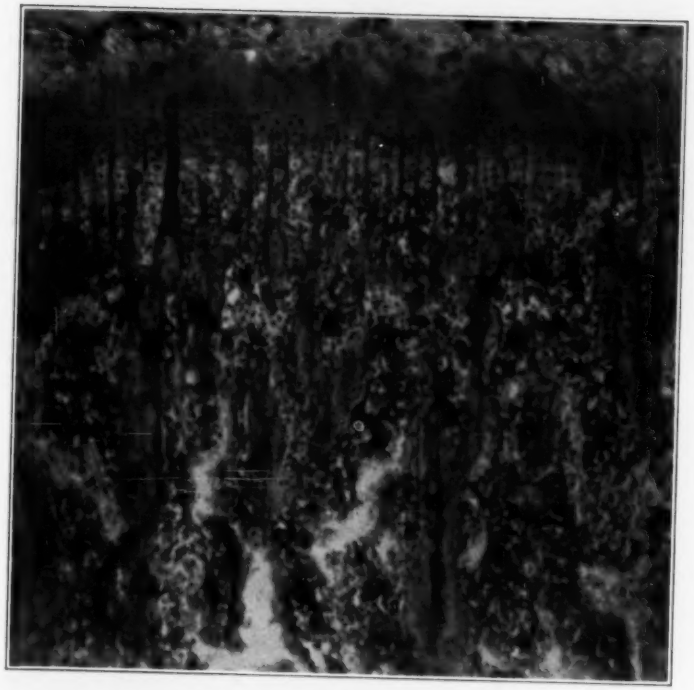

FIG. 3-C

Photomicrograph, after seventy-five days, of control animal whose basic diet had been supplemented with five cubic centimeters of lemon juice daily.

FIG. 4-A

Photomicrograph of growth disc of a pig which had received one-half cubic centimeter of lemon juice for eighty-four days in addition to a scorbutic diet. Note the complete inactivity of the epiphyseal plate and atrophic hemopoietic marrow with multiple dilated blood vessels. One is impressed by the complete absence of bone trabeculae.

FIG. 4-C

FIG. 4-B

Fig. 4-B: Photomicrograph of metaphyseal area of a guinea pig whose basic diet had been supplemented with one-half cubic centimeter of lemon juice for 126 days. The absence of cartilaginous columns or other evidence of growth activity is striking when compared to the control animal.

Fig. 4-C: Photomicrograph of control pig after 126 days showing active longitudinal growth.

FIG. 5-A

Photomicrograph of the proximal tibial epiphysis obtained for biopsy by amputating the leg through the knee joint when painful enlargements about the knees developed in a pig which had received three-fourths cubic centimeter of lemon juice daily for thirty days. This metaphyseal lesion is similar to the acute scorbutic lesion shown in Fig. 1. Note the remains of trabecular framework (*a*) in fibrous marrow (*b*), absorption of cartilage columns (*c*), cortical atrophy (*d*), subperiosteal new bone (*e*), and hemopoietic marrow (*f*).

prepared fresh at frequent intervals, and the pigs had access to food at all times. The diet was supplemented with synthetic cevitamic acid administered subcutaneously, or with fresh lemon juice given by mouth through a dropper. Control pigs received a full ration of vitamin C daily, equivalent to six to eight cubic centimeters of lemon juice in addition to the basic food. Other pigs were fed only the scorbutic diet. These expired in from twenty-five to thirty days, and afforded material for the microscopic study of acute scurvy. The animal groups in experiments A and B received the equivalent of one-half, three-quarters, one, and one and one-half cubic centimeters of lemon juice daily. In experiment C, the daily diet was supplemented with three-quarters of a cubic centimeter of lemon juice. The dietary regimen was not altered after an experiment was started. A detailed protocol of each animal was kept by the author.

Histological preparations were made of the distal radial, proximal humeral, distal femoral, and proximal tibial epiphyses, as well as of the costochondral junctions. The bones were decalcified in 6-per-cent. sulphosalicylic acid, sectioned by the celloidin technique, and stained with hemotoxylin and eosin and by the Mallory method for connective tissues.

Result of Experiment A

The microscopic preparations showed a progressive loss of bone

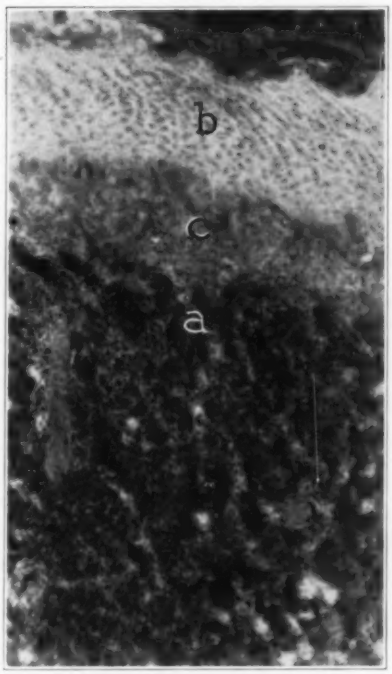

FIG. 5-B

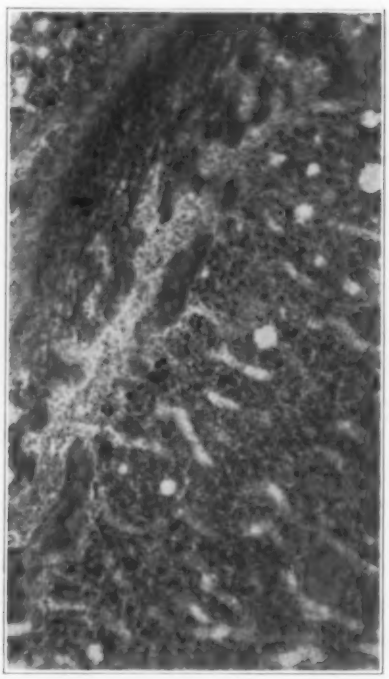

FIG. 5-C

Fig. 5-B: Photomicrograph of thick section of opposite tibia of guinea pig shown in Fig. 5-A, obtained when the eighty-four-day experiment was concluded twenty-five days after six cubic centimeters of India ink had been injected intravenously. The ink-marked marrow (*a*) has been displaced away from the epiphyseal disc (*b*) the distance of (*c*), indicating longitudinal growth had been occurring preceding the death of the animal.

Fig. 5-C: Photomicrograph of a thin section of the distal end of the femur of the same animal shows details of the subepiphyseal region.

trabeculae and calcified columns, indicating decreased growth activity with ultimate suppression of the entire epiphyseal plate. The animals receiving one, and one and one-half cubic centimeters of lemon juice showed the least alterations from the normal. The cartilaginous disc here displayed moderate activity, and the cartilage columns which projected short distances into the metaphysis showed some replacement by bone, and osteoblasts were aligned on their free surfaces. The marrow was hemopoietic and showed no acute scorbutic changes (Figs. 3-A, 3-B, and 3-C).

Guinea pigs receiving less than one cubic centimeter of lemon juice showed interesting changes difficult to interpret. Painful swellings about the wrists, knees, or ankles developed in most of the animals after thirty to forty days, suggesting the presence of an acute scorbutic lesion. After an additional fourteen to twenty-one days, these enlargements subsided, leaving flexion contractures. The histological preparations did not show evidence of acute scurvy in the bone at the termination of the experiment. Most of the epiphyseal discs appeared as narrow, irregular bands of

FIG. 6-A

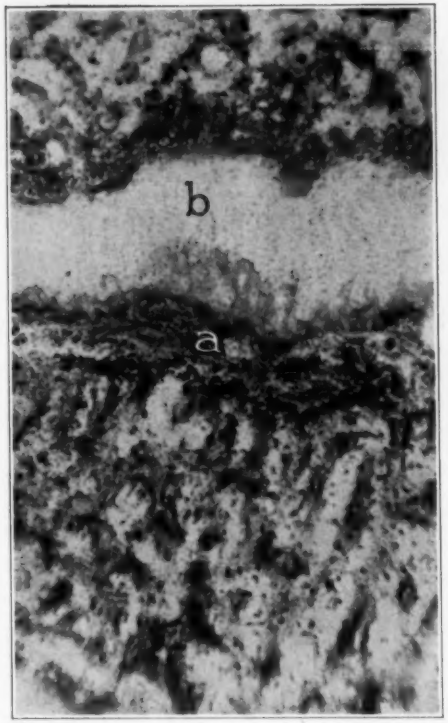

FIG. 6-B

FIG. 6-C

Fig. 6-A: Photomicrograph of growth zone of the proximal end of the tibia, obtained for biopsy after thirty days from a guinea pig whose basic ration was supplemented with three-fourths of a cubic centimeter of lemon juice daily. The fibrous marrow shows only a few remaining fragments of calcified columns.

Fig. 6-B: Photomicrograph of opposite tibia after eighty-one days shows the ink-injected marrow (*a*) bordering on the epiphyseal disc (*b*) and indicates no longitudinal growth had occurred during the last twenty-five days of the experiment. Note that the atrophic hemopoietic marrow shows no signs of acute scorbutus.

Fig. 6-C: High-power photomicrograph shows details of the epiphyseal plate illustrated in Fig. 6-B.

cartilage across the metaphyses, without evidence of growth activity (Figs. 4-A, 4-B, and 4-C). There were no osseous trabeculae or calcified cartilage columns in the unaltered bone marrow of the metaphysis. An occasional animal did show fragments of cartilage columns projecting from the central portion of the plate with some bone on their surfaces.

Comments

Experiment B on longitudinal growth was undertaken to correlate the microscopic appearance of the epiphyseal disc and the state of longitudinal growth during the period immediately preceding sacrifice of the animal. Although thirty-five guinea pigs were utilized, this experiment proved unsuccessful, because the increment of growth could not be followed accurately on serial roentgenograms. However, the necropsy material corresponded in all respects with that already described.

FIG. 7

Photomicrograph of biopsy specimen of proximal tibia obtained after thirty days from guinea pig which had received three-fourths cubic centimeter lemon juice daily. Note the complete absorption of the bone trabeculae and cartilage columns below large segment of plate, and the typical scorbutic marrow.

A more satisfactory means of measuring longitudinal growth was then utilized. Sixty-five animals received three-quarters of a cubic centimeter of lemon juice daily in addition to the basic diet. When the acute lesions appeared about the knees of some animals, a proximal tibial epiphysis was obtained for microscopic study by disarticulating the leg through the knee joint. After recovery from surgery, six cubic centimeters of a 12.5-percent. solution of India ink in saline was injected intravenously. On the eighty-fourth day, that is twenty-five days after the India-ink injection, the animals were sacrificed.

Results of Experiment C

The amputated extremities showed far advanced, acute scorbutic lesions (Fig. 5-A). Bone trabeculae had undergone marked absorption. Although the calcified cartilage columns showed evidence of fractures and absorption, they formed a prominent shadow across the metaphysis in some regions. There was little evidence of new-bone formation, although osteoblasts were present in large numbers. There was a well-developed

Fig. 6-C: High-power photomicrograph shows details of the epiphyseal plate illustrated in Fig. 6-B.

scurvy marrow, as well as extensive subperiosteal new-bone formation. Some specimens showed almost complete absorption of calcified cartilage columns beneath large segments of the growth disc (Fig. 7).

In marked contrast to these lesions, the sections of the opposite tibiae, taken approximately fifty days later, were identical with those of animals in Experiment A which received one-half of a cubic centimeter of lemon juice per day, and showed no microscopic evidence of acute scurvy, although both knees were usually swollen at the time of the biopsy. Although hemopoietic marrow was now present in the metaphysis, it was devoid of bone trabeculae. In those animals in which there was no microscopic evidence of enchondral ossification, the India ink injected twenty-five days previously was present within the reticulo-endothelial cells on the diaphyseal side of the epiphyseal plate, indicating that no longitudinal growth had occurred since its administration (Figs. 6-A, 6-B, and 6-C).

In other animals of this group which did show some microscopic evidences of enchondral growth, the ink-marked marrow was separated from the disc (Figs. 5-B and 5-C). This substantiates the interpretation of the presence or absence of active growth from the microscopic appearance alone.

DISCUSSION

While the bone changes in acute scorbutus are constant and pathognomonic, the microscopic findings in chronic scurvy vary with the degree and duration of deprivation of vitamin C. In the mild form of the deficiency, longitudinal growth may take place in the normal manner, but usually at a reduced rate. In most animals, when the ration of lemon juice is restricted to three-quarters of a cubic centimeter daily, an acute juxta-epiphyseal lesion develops, which undergoes healing without increasing the intake of vitamin C. Histological preparations of a majority of these same animals fifty to sixty days later show an absence or reduction in longitudinal growth.

In none of the sections was there evidence of peripheral growth of the cartilage with arrested central growth. The entire disc participates in any longitudinal growth in scurvy.

The bone changes in chronic scorbutus in humans have not been definitely established. Park, Guild, Jackson, and Bond, in reporting nineteen cases in man, concluded that epiphyseal growth continued, although osteoblasts lost the capacity to form bone. They were of the opinion that the cartilaginous plate retained its normal growth potentialities, and that the calcified cartilaginous matrix was not replaced by bone as in the normal manner, but that the columns accumulated as a "lattice" in the metaphysis, producing a characteristic histological and roentgenographic appearance. Their preparations showed other alterations which are seen also in acute scurvy,—namely, a typical "scurvy-marrow", extreme absorption of osseous trabeculae and cortex, and an increase in the number of osteoblasts.

Neither Ham and Elliott nor the author has observed in guinea pigs the complete suppression of osteoblastic activity while the chondroblasts of the epiphyseal plate continued to form calcified cartilage matrix. Without more definite evidence to the contrary, one could assume that both bone and cartilage formation had ceased, and while all trabeculae of bone had been absorbed by the time of the patient's death, the calcified cartilage columns were undergoing delayed absorption. This point of view finds some support when the metaphyseal "corner lesions", described by Park, Guild, Jackson, and Bond as diagnostic of the earliest phase of chronic human scurvy, are studied. Here one finds not only localized absorption of cortex and bone trabeculae, but also absorption of cartilage columns with fibrous replacement of the immediate hemopoietic marrow.

As newer knowledge accumulates, it is certain that the varied opinions relative to the bone changes in protracted human and experimental scurvy will be harmonized.

CONCLUSIONS

1. Protracted scurvy in guinea pigs is characterized by a suppression of the entire growth zone leading eventually to complete cessation of enchondral ossification in animals whose ascorbic-acid intake is sufficiently restricted.

2. Calcified cartilage columns do not accumulate in the metaphysis as a "lattice" in guinea pigs as, according to the report of Park, Guild, Jackson, and Bond, they do in human cases of protracted scurvy.

3. The activity of osteoblasts and chondroblasts is suppressed, partly or completely, according to the vitamin-C intake. In early acute lesions of chronic scurvy, osteoblasts are present in increased numbers, but do not lay down bone.

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THE IMPORTANCE OF LEAVING A GOOD AMPUTATION STUMP *

BY A. B. LEMESURIER, M.B., TORONTO, ONTARIO, CANADA

The usefulness of any amputation stump depends very largely upon how good that stump is when it is fitted with an artificial limb. With a good stump, the business of fitting an artificial limb is comparatively simple. With the limb on, a good stump is comfortable and can work the limb quite well, and, with a moderate amount of use, should remain comfortable and efficient for a good many years. Unfortunately, not all stumps are good ones. Some lengths of stumps are better than others, some shapes of stumps are distinctly better, and often the trouble in a stump is due to some minor fault which would not be present if the amputation and aftertreatment had been carried out differently. In a war, it cannot be expected that all amputations will be done by experts, but any surgeon who is likely to have to do any amputations, should have a pretty good idea of what constitutes a good stump, and should know how to go about making one.

FIG. 1

A good forearm amputation showing the tapering shape of the stump.

In speaking of a good stump, reference is made, of course, to the stump in its final form. Under war conditions, the first amputation is not always the last one. In a good many cases, the amputation wound becomes infected, and a stump is left that is unsuitable and uncomfortable, or a reamputation has to be done at a higher level. At the time of the amputation, it can usually be pretty well predicted whether the wound is going to heal by first intention or is going to become grossly infected. If it is likely to heal by first intention, or by practically first intention, this amputation should be considered as the last one the man is going to have. It should be done at the best level possible, and should be done with enough care to form a stump that will be permanently efficient and comfortable. If it is likely to become in-

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fected, it is a good rule to consider this primary amputation merely as a temporary measure, to do it at the lowest level that seems safe, and to leave the wound either well drained or completely open, depending upon the severity of the infection. No attempt is made, at this primary operation, to fashion a permanent stump, but at a later date, when it is safe, a reamputation is done at a higher level. There is a proper time to do this reamputation, and it should not be done too soon or delayed for too long. If it is done while the wound is still acutely inflamed, and while the stump is still very oedematous, the wound of the reamputation is almost certain to become infected and to break down. This final reamputation should not be done until the wound on the end is either completely healed or almost healed, and the oedema of the stump has largely subsided. With these reamputations, the sulphonamides should be used, both by mouth and in the wound, but, even with their use, the reamputation should be delayed until the chances of primary healing are very favorable. Primary healing is very important in a final stump, and the less scar there is in the stump, both on its surface and in its depth, the less apt there is to be trouble.

On the other hand, the reamputation is sometimes delayed too long. Some amputation stumps, which are obviously going to be troublesome, are tried out hopefully with artificial limbs, and it may not be until the man has gone through some years of comparative discomfort, that a reamputation is finally decided upon. A late reamputation, done after the man has learned to wear his artificial limb and has become reestablished in a job, is almost a tragedy. He has to go without his limb for some months, and often has to get a new limb and again learn to use it.

The fairest thing to the man is to make as good a final stump as possible before he starts to wear an artificial limb, and before he is discharged from the hospital. There is no great trick about making a good stump if the tissues are available. All that is needed is a certain amount of knowledge and a great deal of care at the operation.

A good final stump, whether it is made at a primary amputation or at a secondary reamputation, should be of the most useful length obtainable under the particular circumstances of the case. In shape, it should taper considerably toward its end, without any bulbous enlargement (Fig. 1). The soft tissues should fit over the end of the bone snugly, with not too much tension and not too much redundancy. It is a great advantage to have as little scar tissue as possible in a stump, and this is one great reason why we like to do the final amputation only when the wound is likely to heal by first intention. The scar should not be adherent to the end of the bone, and should be so placed that it does not press against the bucket of the artificial limb. There should be as little puckering and depression of the scar as possible. A stump so described is not always entirely free from pain, but the better a stump looks the less likely it is to cause trouble.

Before discussing in detail the levels at which amputations should be done, something should be said about end-bearing amputations of the lower extremity. During the years since the last war, we have become convinced, in Canada, that the two end-bearing stumps, the Syme and the Stokes-Gritti, are much better able than the lateral-bearing stumps to carry the body weight, which is the most important function of a lower-limb stump. Amputations at these two levels leave stumps that are particularly adapted for end-bearing in that the end of the bone is broad and smooth and covered by tissue accustomed to pressure. We have tried to obtain end-bearing at other levels, where the bone is not broad, but have found that these stumps will not tolerate weight-bearing on the end for more than a few years.

During the last ten years or so, there have been a good many objections raised against end-bearing amputations, originating chiefly in Roehampton, which is the main amputation center and limb-fitting center in England. They had had little experience there with the Stokes-Gritti amputations, but had had a good many Syme amputations from the last war. Their experience has been that a Syme stump would not tolerate end-bearing for more than a few years, and that the tissue on the end would become so degenerated that, in a large proportion of cases, a reamputation was necessary at the below-knee level. They had a higher opinion of the below-knee stump than we had, because, with it, when the weight-bearing on the head of the tibia became troublesome, the weight was shifted away from the tibia by fitting a blocked-leather ischial-bearing corset to the top of the thigh steels. It was argued that, by taking the weight at first on the head of the tibia until it became unsatisfactory, and by then shifting it to the ischium, it was possible to carry a man through the rest of his life in comfort, without any further amputation and without the loss of the control of the knee joint. It is true that a good many unsatisfactory below-knee stumps can be better treated by a change to ischial-bearing than by a reamputation at the Stokes-Gritti level, which is the other alternative, but, no matter where the weight is carried, a below-knee stump cannot be made to compare in efficiency and comfort

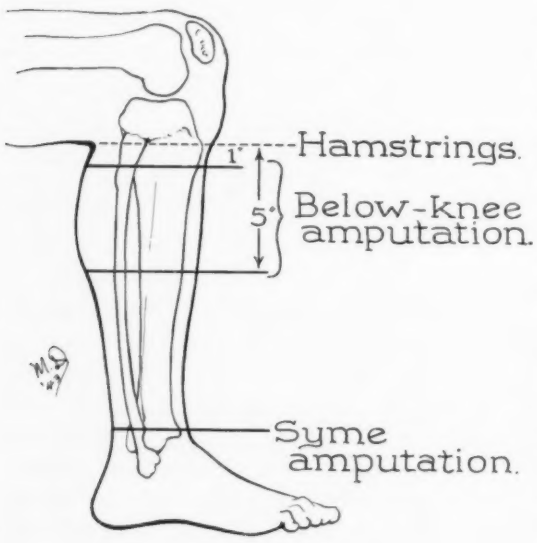

FIG. 2

Level of below-knee amputations.

with a good Syme stump. In Canada the Syme stumps have been almost invariably good, and the ones from the last war have remained good for the years since they were amputated. They cause much less trouble and are seen less often in the amputation clinics than any other type of stump. In the Toronto district, by far the largest amputation center in Canada, there has not been a single Syme stump reamputated since 1921. At the meeting of The American Orthopaedic Association in Toronto in 1941, Gordon Dale, M.B., showed a large number of these end-bearing stumps, both Syme and Stokes-Gritti. All these men were able to get about in their artificial limbs very well, taking the weight on the end of the stump, with no complaints and no obvious signs of vascular degeneration, although their average age was about fifty, and the amputation had been done at least twenty years before. In spite of the criticism, we have seen no reason to change our opinion that the Syme amputation is the best amputation in the lower extremity, and that the Stokes-Gritti amputation is better than any other thigh amputation.

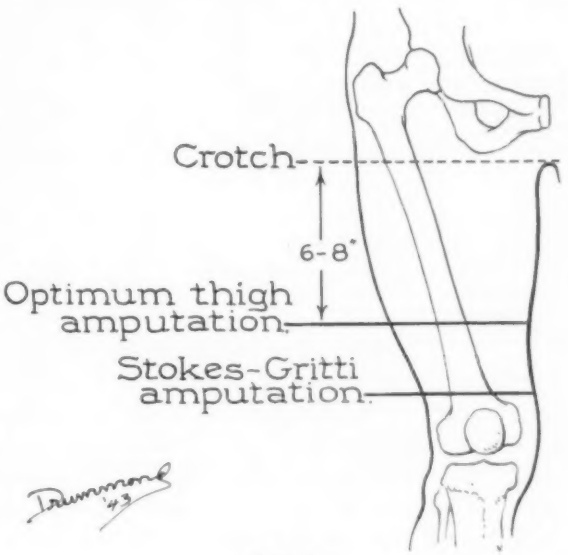

FIG. 3

Level of above-knee amputations.

It is difficult to see the reason for this difference in experience in the two countries. One reason may be that in Canada, during the years 1919 and 1920, practically all the bad Syme stumps were reamputated and only the good ones were left, and any new ones done were done by only four or five surgeons who were familiar with what was required. To be at all satisfactory and durable, the ends of these end-bearing stumps have to be good, as all the pressure is taken here. The operation has to be well done, with the main part of the end-bearing tissue—the heel-flap in the Syme and the patella in the Stokes-Gritti—held in the proper position on the end until it heals there; the wound should heal by first intention and the circulation should be good. One of the most important things about an end-bearing stump is that it should be fitted with a decent end-bearing leg, but, for some reason, it is difficult to get private limb-fitting firms to show any interest in this type of leg.

Not all final stumps are end-bearing, and most of them have to be

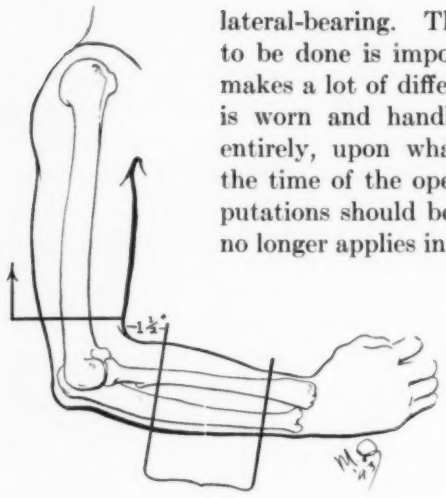

FIG. 4
Level of forearm and upper-arm amputations.

lateral-bearing. The level at which the amputation is to be done is important, as the length of the stump makes a lot of difference in the way the artificial limb is worn and handled. It depends largely, but not entirely, upon what healthy tissue is available at the time of the operation. The old rule, that all amputations should be done at the lowest level possible, no longer applies in every case. Amputations at some levels make stumps that are too long to fit the modern artificial limb, or so long that in time the circulation at the end fails. Other amputations may make stumps that are called too short, that is the part of the stump below the knee or elbow is too short to stay in the bucket of the artificial limb, and the amputation is better done above the joint. The level at which amputations should or should not be done has been pretty well worked out for different regions, but in order to lay down any set rules for the length of the stumps, some standard system of measurement should be adopted. The only part of the stump whose length really matters is the part that protrudes beyond the region of the joint above, — that is, in the leg, the part that projects beyond the lowest hamstring insertion when the knee is flexed; in the thigh, the part that projects beyond the crotch; in the forearm, the part that projects beyond the fold in front of the flexed elbow; and in the upper arm the part that projects beyond the anterior axillary fold. If any fixed bony point above is used for measurement, the length of the projecting part varies very much in individuals of different sizes. The best way to measure the length is from the point beyond which the stump projects, such as the hamstring insertion or the crotch. Unfortunately, it is not always easy to define these points accurately when the patient is prepared for operation, and it is a good plan to place, before the operation, an indelible mark on the skin at the level at which the bone is to be divided.

As has been said, the Syme amputation is the best in the lower extremity. Unfortunately there are few cases in which a good stump can be made at this level. If a Syme amputation cannot be done (Fig. 2), the next best level is somewhat above the middle of the leg, about four or five inches below the lowest hamstring insertion. A stump longer than this is no more efficient, and is apt to be uncomfortable and to have trouble with its circulation. These below-knee amputations are best done by anterior and posterior flaps, the anterior one being longer, so that the scar lies behind the end of the stump. The front corner of the tibia should be rounded off considerably and the fibula should be divided about an

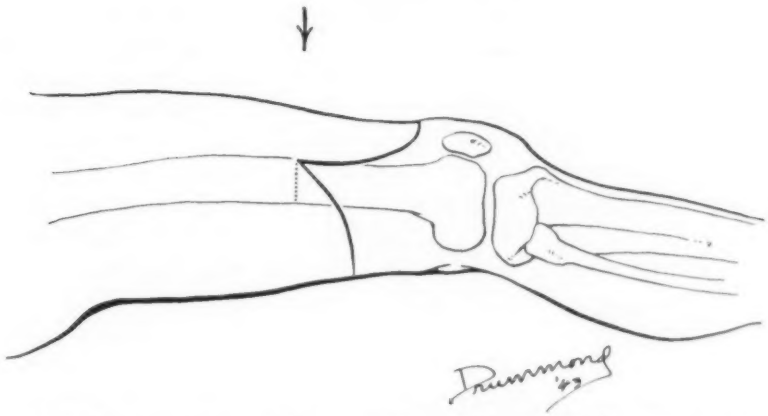

FIG. 5-A: Level of bone section and outline of flaps in thigh amputation.

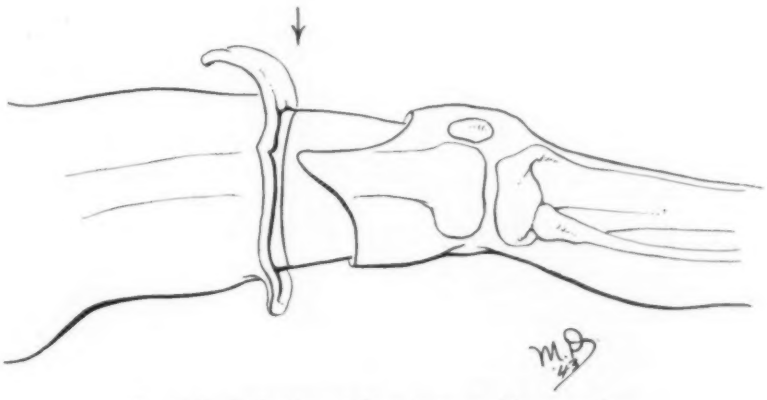

FIG. 5-B: Reflection of flaps to level of bone section.

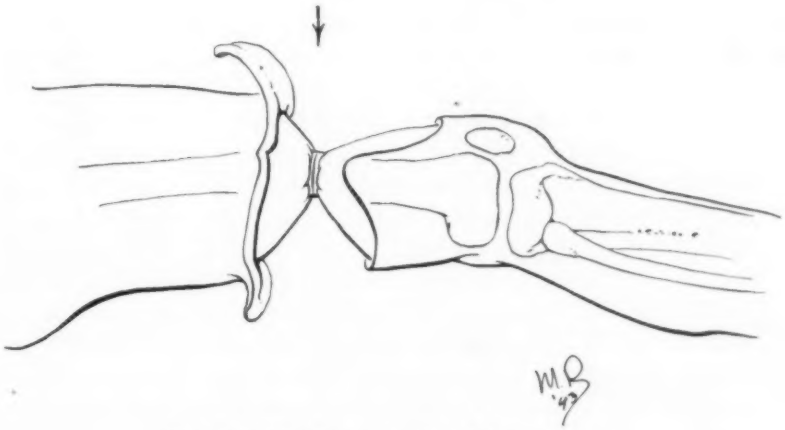

FIG. 5-C: Muscles are sectioned down to bone.

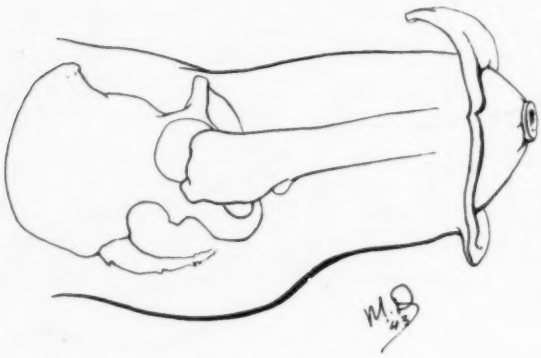

FIG. 5-D

The bone has been divided and the limb removed. The retracted cut muscles assume a tapering shape.

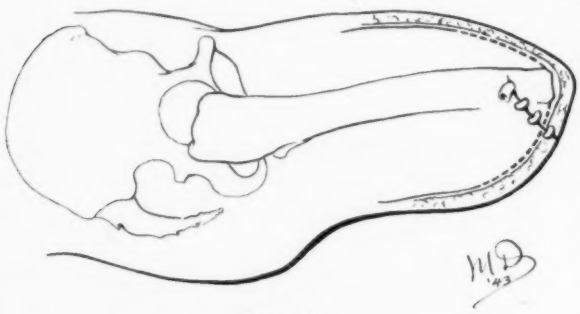

FIG. 5-E

The flaps have been sutured over the end.

inch shorter. If the amputation cannot be done four inches below the hamstrings, it should be done as close to this as possible. Any stump projecting less than one inch below the hamstrings will not stay in the bucket of the artificial leg, and if this length cannot be obtained, the amputation should be done above the knee, as a disarticulation of the joint is unsatisfactory. The best level above the knee is the Stokes-Gritti level, with the femur divided above the condyles and the patella fixed to the end. This is an end-bearing amputation, and should not be done unless a good stump can be made with a well-nourished anterior flap of decent length. If a good Stokes-Gritti stump cannot be made, the next best level (Fig. 3) is at the junction of the lower and middle thirds of the femur, about six to eight inches below the crotch. These above-knee amputations are best done by anterior and posterior flaps, the anterior being somewhat longer. If a length of six inches below the crotch cannot be obtained, as much as possible should be left. A stump as short as three inches from the crotch can carry an above-knee leg, but its control is difficult, and the man should wear a pelvic belt harness. A thigh stump less than three inches long will not stay in the ordinary above-knee bucket, and a tilting-table leg should be worn. This can be fitted to a disarticulation of the hip, but can be better fitted if some of the femur is left, even if the amputation is done through the base of its neck.

In the upper limb, any amputation through the wrist joint or through the lower third of the forearm leaves a stump which is difficult to fit with an artificial arm, and the arm is unsightly and cumbersome. The best amputation through the forearm (Fig. 4) is at the junction of the lower and middle thirds. Above this, as much length should be saved as possible. Any stump projecting less than an inch and a half from the fold in

front of the elbow is too short to work the elbow joint of the artificial arm, and the amputation should be done above the joint. A disarticulation of the elbow or an amputation through the lower end of the humerus is bulbous at its end and difficult to fit. The best amputation through the humerus is about two or three inches above the elbow, and above that, as much as possible should be left. With even a very short stump, an artificial arm can be worn, but it cannot be moved about at all effectively unless the stump projects at least an inch beyond the axillary fold. All amputations of the upper extremity are best done by anterior and posterior flaps of equal length, leaving the scar on the end.

With the exception of the Syme and Stokes-Gritti amputations, which have to be done according to the textbook description, all amputations should be done in the simplest way, and in the way that leaves least scar tissue in the stump; this is usually by two flaps,—an anterior and posterior. Except for the end-bearing stumps which are somewhat bulbous, all stumps, whether of the upper or lower extremity, should taper toward their end, as with this shape they are more easily fitted with an artificial limb, and are better able to handle the limb. It is a great disadvantage to leave a redundant amount of skin or a mass of soft tissue on the end of the stump, and it is much better to have no muscle at all over the end of the bone. The flaps need consist only of the skin and the full thickness of the subcutaneous fat, and this is quite enough protection for the end of the bone.

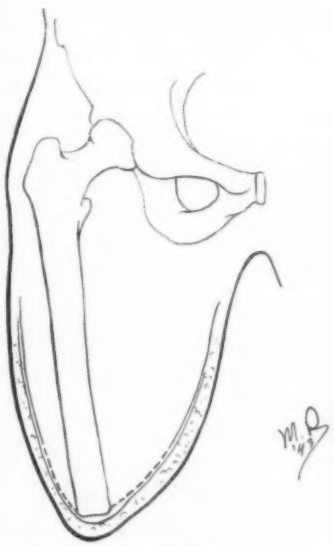

FIG. 5-F
Front view of thigh amputation at the completion of the operation.

At the operation, before outlining the flaps, the level at which the bone is to be divided is first determined. The incisions start on either side at this level, and outline the two flaps (Fig. 5-A). These flaps should not be cut too squarely at the end, but should be considerably tapered, to avoid any excessive fullness of the skin at the corners of the stump when it has shrunk. The flaps should be just long enough to cover the end, without any tension and without any redundancy. In marking them out, the combined length of the two flaps should be slightly greater than the diameter of the limb at this level. If one flap is longer than the other, it should be slightly narrower, so that the cut surfaces of the two will be of equal length and can be sutured accurately. These flaps, consisting of the skin and full thickness of the subcutaneous fat, are then dissected upward to the level at which the bone is to be divided (Fig. 5-B). At this level the muscles and other soft tissues are then divided circularly

down to the bone; this allows them to retract, leaving a cut end tapering in shape (Fig. 5-C). There is no point in separating the muscles from the bone above where it is going to be divided. The less dissection there is during the operation, the less scar formation there will be. For the same reason, it is unnecessary to denude the bone of its periosteum for any distance above its section. Bony spurs sometimes form, but practically never cause any trouble. The simplest and least damaging way is to divide the periosteum circularly at the same level at which the muscle has been cut and at which the bone is to be divided, and then to elevate it far enough to prevent it from interfering with the action of the saw, which need only be about an eighth of an inch. The bone is then divided and any sharp corners rounded off. The same holds true in the treatment of the large nerves. The less damage done to the cut ends, the less discomfort the patient has, particularly during the first couple of weeks. No matter what is done, whether alcohol is injected or a fish-mouth cut is made, a neuroma will form on the end. The neuroma, by itself, usually causes little trouble, unless it is subjected to pressure or is adherent to the scar. It is best lying in a normal intermuscular plane above the cut end of the muscles, and this position can best be obtained by pulling it down moderately, dividing it cleanly by a sharp knife and allowing it to retract. The large nerves, particularly the sciatic, have a fair-sized vessel with them, and this should be tied separately, or the whole nerve tied. There is nothing particular in dealing with the blood vessels, except that all bleeding should be stopped before the wound is closed. When it is possible, all amputations should be done under a tourniquet. When the bone has been divided and the limb removed, all the blood vessels that can be identified are clamped and ligated. For the larger arteries, the ligatures should be fairly stout and tied tightly enough to crush the intima, and tied securely, and for very large arteries, it is wise to apply two ligatures, a short distance apart, in case one should slip. If there is any likelihood of infection it is unwise to use non-absorbable ligatures as these are likely to cause persistent sinuses until they are removed. When all the vessels that can be identified have been tied, the tourniquet is removed. Any further bleeding points, and there are usually a great many, are clamped and either tied with fine ligatures or touched with a cautery. This making of the wound bone-dry takes some time. In the days before anaesthetics, the surgeons used to pride themselves on being able to complete an amputation in five minutes, but now there is no need of speed, and the time taken here is worth while. At this stage, with the wound wide open, the cut end of the bone is the most prominent projection (Fig. 5-D). The cut muscle near the bone is almost at the same level, but farther away tapers back considerably. No attempt is made to suture the muscle. The flaps, consisting of skin and subcutaneous fat, are then brought over the end and their edges are sutured accurately in two layers,—one the subcutaneous fat and the other, the skin. There is almost certain to be some oozing of blood after the operation, and to prevent the

formation of a hematoma under the flaps, a small drain is inserted into one end of the wound, and a fairly tight bandage is applied, and is kept from slipping by adhesive plaster.

The immediate postoperative treatment of the stump consists largely in leaving it alone. The dissection of the muscles and flaps has been fairly extensive, and the whole part should be kept at rest as much as possible to allow it to heal. In the first two or three weeks massage does more harm than good, and active movement should be discouraged until the healing in the depth of the wound is sufficiently far advanced to make it painless.

There is an interval between the time that the wound heals and the time that the man can wear an artificial limb. The dissection at the operation has been so extensive that it takes about a month before it is healed soundly enough to stand much pressure or much movement. Another reason is that after an amputation a stump always shrinks, rapidly for the first month and then more and more slowly. It is expensive to get a finished artificial limb until the shrinking has almost finished. The shrinking can be hastened best by the use of a crepe bandage which is applied evenly and fairly firmly, and which exerts, as much as possible, pressure from below upward. The proper application of this pressure bandage requires a fair amount of skill, but, in the lower limb, the patient can learn to do it himself fairly well. The bandage should be changed two or three times a day, when it becomes too loose or too tight, and should be worn the whole twenty-four hours. The temporary limbs are not of much use in the upper extremity or in below-knee amputations; in the latter case they are not so useful as the bandaging. In thigh amputations, the author believes they are good, but in these, the buckets, usually made of plaster, should be carefully made and should be of much the same shape as the permanent bucket. He thinks, too, that it is a mistake to wait until the shrinking is entirely finished before supplying a complete limb. With adequate bandaging, most of the shrinking has taken place in three months after the wound has healed, and a completed limb can then usually be worn quite well. It is true that further shrinking will probably make another bucket or another leg necessary in about three months, but getting the man back to work sooner justifies the additional expense. While waiting for the shrinking to occur, the man should systematically exercise the muscles that control the stump, and, when he gets his artificial limb, he should be carefully instructed in its use.

The author has said a good deal, but has not gone much into detail. The main point that he is trying to make is that too many final stumps are not so good as they should be. The discomfort from them may not be very great, but it is more or less constantly present for the rest of the man's life, and is likely to become worse as the man and his arteries become older. To the man himself the stump is of considerable importance, and to the surgeon it should be of some importance, at least enough to make him take the trouble to fashion it so that it will be as efficient and comfortable as possible.

THE USE OF CELLOPHANE AS AN INTERPOSITION MEMBRANE IN SYNOVECTOMY

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Observation of the postoperative course of a number of cases of arthritis, subjected to synovectomy, cannot fail to impress one with the extreme difficulty of restoring motion to the joints operated upon. The knee is the joint most frequently subjected to this procedure, and also the most difficult joint to restore to motion after such an operation. At best, several weeks of strenuous exercise and painful physiotherapy are necessary to secure a range of motion of 90 degrees, and such a range may be considered a satisfactory result. The personal factor in this recovery is extremely important. In a large percentage of patients, whose tolerance to pain is low and whose physical stamina is impaired by chronic disability, the terminal state may be complete fibrous ankylosis. Any procedure, by means of which this difficult period can be circumvented, would seem worthy of consideration.

About five years ago, the author had occasion to see into a knee joint which had been subjected to synovectomy two years before. The postoperative course had consisted of several weeks of very strenuous and forcible physiotherapy. The patient (Case 3) was robust and very determined. Only the one joint had been involved. Somewhat less than 90 degrees of flexion was secured, in spite of prolonged effort, and there was a coincident loss of stability. At the second operation, it was noted that the suprapatellar pouch had been destroyed, and that very firm adhesions held the patella tightly fixed in place, so that, functionally, the upper border of the patella was hinged to the femur at a point just above the femoral articular cartilage. It seemed reasonable to suppose that if the suprapatellar pouch could have been preserved at the first operation, the postoperative course would have been less strenuous, the range of motion better, and the functional end result much more satisfactory.

In March, 1940, a case of villous arthritis of six years' duration was seen (Case 1). It is not the purpose of this paper to discuss indications for or merits of synovectomy, and, therefore, a detailed case history will not be given.

The disease was of six years' duration, involved both knees and one ankle, and had kept the patient bedfast over 50 per cent. of the time since the onset, with recurring effusion, chronic swelling, and severe pain. Because of beginning flexion contracture and the fact that it was the first joint involved, only the right knee was operated upon at first, on April 2, 1940, according to the technique to be described.

A median parapatellar incision was made, and all of the synovial membrane in the suprapatellar pouch, intercondylar notch, and beneath the lateral ligaments was removed. Every bit of synovial membrane accessible through this incision was excised. Both semilunar cartilages

were excised, and roughened bone and cartilage surfaces were smoothed with osteotome and scalpel. All pannus was rubbed and curetted from the cartilage surfaces. The synovial membrane was very much thickened, and of chronic inflammatory character. It weighed seventy-five grams.

A previously autoclaved piece of cellophane was then cut in a pattern to fit the suprapatellar pouch, and to extend laterally and medially to permit the ends to lie under the lateral ligaments where they crossed the joint (Figs. 1-A and 1-B).

A method of holding the piece in place, by means of holes through which adhesions would grow, had been preconceived. This seemed impractical and unnecessary in this situation and was abandoned.

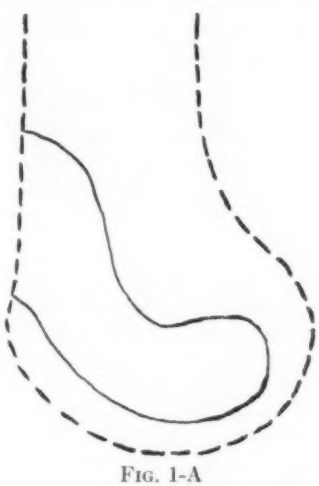

FIG. 1-A

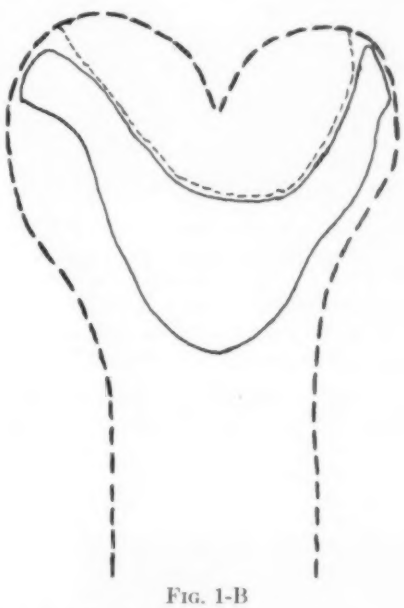

FIG. 1-B

Size and relative position of the piece of cellophane.

It might prove useful elsewhere. The incision was closed, and a heavy cotton-and-gauze pressure bandage was applied.

The results in this case were even better than the author's enthusiasm had led him to expect.

Entirely unassisted motion was started on the fourth day. On the ninth postoperative day there was 85 degrees of pain-free flexion, and extension to the point of the original contracture (Figs. 2-A and 2-B).

The patient repeatedly said this motion was not painful, and complained only of the area of skin anaesthesia incident to the incision. No further definite effort was made to increase the range of motion, but it rapidly increased to 130 degrees (Fig. 2-C). The flexion contracture disappeared. Unassisted weight-bearing was started in ten days.

On May 30, 1940, a similar operation was performed on the second knee, and, with the consent of the patient, the first knee was reopened. A smooth, glistening surface was found throughout the area in which the cellophane had been interposed, and a suprapatellar pouch of normal extent was present. The cellophane had split in the center and the edges were fragmented. There was no evidence of reaction to it other than as a mechanical barrier modifying the formation of scar tissue. This was confirmed later by micro-

scopic study of a piece of the tissue which had been removed as a biopsy. Because the cellophane seemed to produce no reaction, and since in the future the author proposes to leave it in the joint, no attempt was made to remove any of it except a small piece for examination. This had in every way the initial gross appearance, except for mechanical fragmentation.

In the second knee, motion was not started until the end of one week. (The first knee had moved so freely that the author was somewhat fearful of the security of the incision.) Four days after motion was started, there was 80 degrees of pain-free motion without any physiotherapy at all. Weight-bearing was then instituted. The range increased rapidly to normal. The exploratory arthrotomy on the first knee had in no way interfered with its motion.

The patient was somewhat debilitated by long illness and was not tolerant to pain. She secured this postoperative result through her own effort. When her postoperative course is compared to that of many others who have gone through unquestioned torture and exhausting effort to secure a usable range of motion, the benefit of the small piece of cellophane seems unquestionable.

When last seen, she still had a full normal range of motion in both knees. The arthritic process was quiescent, and had remained so except for one occasion in 1941 when she permitted herself to lose twenty-five pounds of weight and to get into bad general condition. She had completed a course in business college, and was working, and able to dance well. She was taking no medication other than that directed toward maintaining a good state of general health.

CASE 2. In August, 1940, a female, aged fifty-five, came under observation. Twenty-three years previously, she had had a pregnancy which terminated in the death of the foetus at five months and retention of the foetus for eight months. During this time, she had what must have been a severe general toxic neuritis with resulting complete flexion contracture of both knees, which had resisted all efforts at correction until tenotomies had been done. Full motion had never been restored, and the patient walked finally with a cane. In May, 1940, she had fallen and fractured the right femur through the condyles. There had been anterior angulation, and the fracture had been put up in what was thought to be flexion in the

FIG. 2-A

Case 1. Range of flexion nine days after operation.

FIG. 2-B

Range of extension nine days after operation.

knee joint, but was really in 40 degrees of angulation at the fracture. Union had occurred in this position, and when seen there was no knee motion present. A wedge osteotomy was carried out, and the angulation was corrected; through the same incision, the suprapatellar pouch was exposed. It was completely obliterated by heavy scar-tissue adhesions. A new space of approximately normal proportions was dissected out, and all adhesions were freed. A piece of cellophane was interposed. The incision was closed and a cast was applied with a Steinmann pin through the bone to maintain positive alignment. Union occurred and the cast was removed in eight weeks. Free flexion of the knee to 45 degrees was present at once. Without physiotherapy or any effort, other than that of the patient, flexion to 90 degrees was obtained, and the patient, who had always walked with a cane because of some flexion contracture in this knee, now walks without one.

FIG. 2-C

Range of flexion finally obtained.

The knee mentioned in the opening remarks (Case 3) remained under continuous observation. The arthritic process did not progress. The instability, both lateral and anteroposterior, increased; the quadriceps was functionally inactive; and the patella was fixed, though not by bony ankylosis. A diagnosis of gouty arthritis was established, the original diagnosis of villous arthritis being obviously mistaken. It was anticipated that some surgical procedure would be imperative when flexion contracture developed to the point of insecurity. This occurred in 1941. The patient refused arthrodesis which was offered as an alternative to an attempt at reconstructive surgery. At operation, the joint was found to be in a rather serious condition. There was marked loss of cartilage with eburnation of the bone over the weight-bearing surfaces. The modified synovial membrane had reformed in pockets connected with the joint. They were lined with a thick yellowish membrane, and the joint contained about 100 cubic centimeters of dirty gray fluid which was sterile. The suprapatellar pouch was absent, as previously noted. All modified joint lining, which had none of the appearance of synovial membrane, was removed. The undersurface of the patella was removed, and a piece of fascia lata was sutured over it. All bone edges were removed where they might produce mechanical irritation. The suprapatellar pouch was reconstructed, and cellophane was interposed. The incision was closed, and a pressure dressing was applied. The knee was put in 45 degrees of flexion by means of a plaster splint.

As anticipated, the patient had a violent attack of gout twenty-four hours later, involving the affected knee and the left subdeltoid bursa; this was given medical treatment. Motion was started about the tenth day. No physiotherapy was given; complete extension and weight-bearing were not permitted for three weeks, to allow the relaxed lateral ligaments to contract to some extent. The patient was able to ride horseback four weeks later, and walked with a cane. Pain on weight-bearing persisted until the flexion contracture was overcome. Stability improved markedly, and the cane was discarded. The patient is now able to ride well, although he mounts on the off side, and can walk along the bank of a stream and fish. Improvement is still continuing and has been greater since routine medication and strict adherence to diet have kept the gout under fair control.

CASE 4. In May, 1942, a doctor, aged sixty-nine, was seen. He had known he had a loose body in the knee for over forty years. It had bothered him a great deal at first,

and then had remained completely quiescent for over thirty-five very active years. In 1939, he slipped in a boat and injured this knee. It became acutely swollen. Insecurity, locking, and a fixed flexion contracture developed. Over the next three years disability had been progressive, and some chronic effusion was present at the time of the examination. Roentgenograms showed one large loose body and at least two smaller ones, one of which was in the posterior compartment.

On opening this knee, the anterior loose bodies were readily removed. The synovial membrane was very greatly thickened, and was covered with hypertrophied villi. Complete synovectomy was done including removal of both semilunar cartilages. Roughened bone edges at the sites of cartilage destruction were removed. A piece of cellophane was interposed in the suprapatellar pouch with extension beneath the lateral ligaments. The posterior compartment was opened and the cartilage body lying in it was removed. This was firmly attached to synovial membrane, and probably was not producing symptoms. Motion was started in one week. Three physiotherapy treatments were given (chiefly to allow the physiotherapist to compare the ease of motion in this joint to that in many other knees subjected to synovectomy without cellophane). At four weeks, the flexion contracture was gone, the patient walked with scarcely any limp, and he has resumed all normal activity. Flexion is now normal, and there is no limp. The patient recently walked twelve miles in one day on a hunting trip over rough country.

The thickness of the piece of cellophane does not seem to be important. The thinnest possible piece would probably produce the desired result, but the thinner grades are very hard to handle and tear easily. Cellophane No. 300 was suggested by the manufacturers. It is not waterproofed as are many grades of cellophane. It is sterilized by autoclaving and kept smooth by rolling it into a roll between two fairly heavy sheets of paper.

The uses to which cellophane might be put as an interposition membrane are, of course, limited only by the imaginative scope of the operator, and anyone can immediately think of many situations in which it might be useful. In the author's opinion, its purpose of causing modification in the formation of scar tissue, so that adhesion of two surfaces is prevented, is achieved in a few days, and it might then be removed. However, at present, no reason can be seen for not leaving it *in situ*.

PARALYTIC SCOLIOSIS *

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During the epidemic of infantile paralysis in the State of Iowa in 1940, 264 patients with this disease were admitted to the Orthopaedic Department of the State University of Iowa. Thanks to the foresight of Dr. Arthur Steindler, in more than 100 cases, as soon as the condition of the patient permitted, roentgenograms of the spine were taken, regardless of the muscle involvement and the severity of the disease. The examination and evaluation of this material (Early Series) and its comparison with more than 100 cases in previous epidemics (Late Series) form the basis of this paper.†

Our observation shows that in most cases from four to five years are necessary for the complete development of paralytic scoliosis. Only after that period can a scoliotic curve be regarded as mechanically final; this also marks the end of the early stage.

PRELIMINARY REMARKS

1. The mode of production of scoliosis is not a physiological or a hyperphysiological articular motion. As can be demonstrated in habitual and rachitic scoliosis, the penetration of the spine into the space surrounding it, toward the thoracic cavity or the pelvic crest, is chiefly a *translatory shift*,—the vertebrae slip into the surrounding space without much lateral tilting. The wedging of the vertebrae on the concave side follows very soon in habitual and rachitic scoliosis; this fails to occur, however, in physiological scoliosis and in many cases of paralytic scoliosis.

2. The compression of the healthy intervertebral discs is slight, as seen in the roentgenograms of patients bending to the side or standing. The sites of chief pressure are the intervertebral discs between the tenth and the eleventh, and the eleventh and the twelfth thoracic vertebrae, and between the twelfth thoracic and the first lumbar vertebrae.

3. Physiologically there are no motions of the spine by itself. The spine normally moves only when the shoulder girdle, thorax, pelvis, and head move; these are the "master organs" of the spine. This implies

* Sponsored by The National Foundation for Infantile Paralysis, Inc., New York, N. Y.

† Throughout this entire article the illustrations are used so that the roentgenograms show the left side of the patient at the left side of the page. It is usually customary for *The Journal* to show roentgenograms of patients as though the reader were looking at the patient (the left side of the patient toward the right side of *The Journal* page). An exception is made in this case, because of the lettering which had been done by the author on the reverse of the roentgenograms. All the roentgenograms shown are anteroposterior views, except the few lateral views.

that there are no muscles which permit the spine to move by itself,—hence there are no muscles which directly produce, prevent, or correct scoliosis.

4. *Scoliosis is the motion of the spine by itself*, its penetration into the space surrounding it (thoracic cavity and abdominal space), regardless of the motion of the "master organs". The erectors of the trunk, when contracting on both sides simultaneously, pull the trunk backward. In lateral bending, the erector muscle of the side toward which the motion occurs relaxes; the erector muscle on the other side contracts. Lateral bending is brought about chiefly by the lateral abdominals. The protection of the spine against lateral deviation is of a *passive nature*, the contributing factors of which are:

a. the ribs;
b. the ligaments;
c. the discs;
d. the physiological sagittal curves, especially the lumbar lordosis;
e. the resistance of the vertebrae themselves;
f. the respiration.

The alteration of the balance of the master organs alone (muscle imbalance) is not sufficient to produce scoliosis. As will be shown in infantile paralysis, besides the muscle imbalance of the master organs, there is derangement of the ligamentous apparatus, the discs, the physiological sagittal curves, and the respiration; hence, the danger of the development of scoliosis is imminent.

THE PARALYTIC SPINE

Prior to the lateral deviation, after an attack of infantile paralysis the spine shows features characteristic of the *paralytic spine*. It is necessary to speak of the paralytic spine instead of the scoliotic spine, since at the onset there is no lateral deviation, but the spine discloses a significant pathological condition apparently due to poliomyelitis. No deviation can be observed in the roentgenogram, but there is *rotation* of the vertebrae. The rotation usually precedes the lateral deviation, and months may pass before the lateral deviation is established.*

Several kinds of rotation can be observed in the roentgenogram:

1. *Univertebral rotation* in which only one or two vertebrae are rotated. This is a temporary feature.

2. *Segmental vertebral rotation* in which most of the vertebrae of the same segment are rotated in the same direction (Fig. 1-B).

3. *Alternating vertebral rotation* in which most of the vertebrae of

* In order to establish the direction and the mode of vertebral rotation, it is necessary to consider the spinous processes, the shadows of the articular processes, and, in the lumbar spine, the position of the intervertebral structures. The study of all three factors is indispensable, as the direction of the spinous processes is subject to wide variations in normal vertebrae. The displacement of the shadow of the intervertebral structures in the lumbar spine is the earliest sign of rotation. These structures are displaced to the side toward which the vertebral arch points. Therefore, in discussing vertebral rotation, the author is referring to all three factors.

Fig. 1-A

Fig. 1-B

C. H. (No. 248). Male, eighteen years of age.
Fig. 1-A: December 7, 1940. Roentgenogram taken in the supine position shows alternating rotation of the thoracic vertebrae.
Fig. 1-B: May 8, 1941. Roentgenogram taken in the supine position shows segmental rotation. The spinous processes of the sixth to the twelfth theracic vertebra point to the left.
Note the atrophy and calcium deposits in the intervertebral spaces.

the same segment are rotated in alternate directions (Fig 1-A). This phenomenon is characteristic of the thoracic spine.

4. *Rotation of the spinous processes* occurs in one of the following forms:

a. All or most of the spinous processes point in one direction.

b. The spinous processes of the first seven to nine thoracic vertebrae point to one side, and the spinous processes from the tenth, eleventh, or twelfth thoracic vertebra to the fourth or fifth lumbar vertebra point to the opposite side.

c. The spinous processes of the first to the fourth or fifth thoracic vertebrae point to one side, while the rest of the spinous processes remain in the middle line. This is the least frequent type of rotation, and is encountered chiefly in isolated deltoid paralysis.

Following or accompanying this rather rigid pattern of the direction of rotation, lateral deviation appears. The amount of rotation is greater than we are accustomed to in scoliosis of any other etiology.

Lateral deviation is preceded by rotation (Fig. 2-A), but does not always follow it. Especially in individuals who have contracted infantile paralysis after puberty, the spine frequently shows rotation only, or very little lateral deviation (Fig. 3-A).

There are three main factors which are responsible for the rotation of the vertebrae:

1. Rotation of the pelvis.
2. Rotation of the thorax and of the shoulder.
3. Respiration.

Rotation of Pelvis

The rotation of the pelvis is one of the most powerful rotary functions which the human body possesses. The elaboration of the step during locomotion is due mainly to the forward swinging of one side of the pelvis. This mechanism, unchecked, would be powerful enough to damage the entire articular apparatus, especially that of the lumbar spine. To prevent this, the mighty system of discs developed. *These discs represent the main antirotary system of the spine*, checking and blocking rotation and realigning the spine after the rotation of the pelvis has ceased and the step has been completed. The onion-like layers of the intervertebral discs in the horizontal section, their fibers meeting at an angle of about 60 degrees in the frontal section, are arranged in such a way as to overcome the dangers menacing the articulations by rotation. The alignment of the system of discs into their original position is also guaranteed by the great elasticity of the ligamentous apparatus and discs.

The effect of the pelvic rotation is revealed in the roentgenogram. The shadows of the iliac bone are narrowed on the forward-swinging side, and are widened on the other side.* Pelvic rotation can be brought

* This is, however, not a constant sign. Simultaneous forward-backward tilting of the pelvis or rotation of the sacrum by itself at the sacro-iliac junction frequently interferes with this roentgenographic evidence of pelvic rotation.

FIG. 2-A

FIG. 2-B

FIG. 2-C

A. H. (No. 202), female, eleven years of age, had a spotty paresis of the muscles of the upper and lower extremities and of the abdomen, with pelvic rotation to the right.

Fig. 2-A: December 11, 1940. Patient has a straight spine, with the spinous processes of the first thoracic to the fifth lumbar vertebra pointing to the left. This is the rotation preceding lateral deviation. Lumbar intervertebral spaces are enlarged.

Fig. 2-B: October 15, 1941. Roentgenogram taken in the supine position shows the intervertebral spaces to be markedly narrowed.

Fig. 2-C: October 15, 1941. Roentgenogram taken in standing position shows the lumbothoracic curve pointing to the right. All spinous processes point to the left. A compensatory curve, pointing to the left, is beginning in the lower lumbar region.

FIG. 3-A

FIG. 3-B

M. N. (No. 285), female, fourteen years of age, with pelvic rotation.

Fig. 3-A: July 26, 1940. The thoracic intervertebral spaces are enlarged. The spinous processes point to the left, and there is no lateral deviation.

Fig. 3-B: September 26, 1941. The intervertebral spaces are compressed; the spine is cloudy, as though veiled. The rotation and curve are unchanged.

FIG. 3-C

FIG. 3-D

Fig. 3-C: July 26, 1940. The intervertebral spaces of the lumbar spine are dark and translucent. The spinous processes point to the left.

Fig. 3-D: September 20, 1941. The intervertebral spaces are cloudy and compressed. Rotation is unchanged, and there is no curve.

about by contracture of the hip; even the sinking of the atrophied side into the mattress can give the other side a relative amount of forward swinging, causing pelvic rotation. Usually, during locomotion, the leg with the better hip muscles swings farther than the other leg. Many exceptions to this rule have been found. In the first place, the leg with gluteus medius paralysis swings more to the front than the other leg; further, if there is any equinus of the foot, the latter has to be advanced more than the other one in order to touch the ground with the entire sole. In the same way, the shorter leg needs more time to reach the ground, prolonging the swinging period of the side concerned. All kinds of equinus—equinovarus and equinovalgus—and even the serious valgus position of the foot may prolong the swinging period of one side, producing pelvic rotation. The main source of pelvic rotation is, however, the predominant strength of the hip muscles on one side. Rotation of the pelvis rotates the entire lumbar spine, the inferior part of the thoracic spine, and, in many instances, the whole spine.

FIG. 4-A

M. B. (No. 252), female, aged twelve years, had involvement of the muscles of both lower extremities and of the abdomen. A curve was developing in the sitting position.

November 6, 1940. The spine is straight and the thoracic spinous processes are in alternating rotation, but the lumbar vertebrae are rotated to the right. Notice the articular surfaces and the intervertebral structures; the latter in the lumbar region are pushed to the left and the spinous processes are pointing to the left slightly.

Scoliotic curves caused by pelvic rotation show rotation of the vertebrae in the same direction. Sometimes, some of the uppermost vertebrae may point to the opposite side, but this condition is permanent only in a small fraction of cases.

Another phenomenon following pelvic rotation is narrowing of the side of the thorax toward which the rotation is directed and enlargement of the opposite side. This happens because the rotating spine penetrates the thorax, compressing the vertebral ends of the ribs toward which the rotation is directed, and stretching those of the other side.

Scoliotic curves originating in pelvic rotation are usually of favorable prognosis, except for cases in which constant sitting ("sitting curves") had initiated the ominous pelvic obliquity. Patients with sitting curves, regularly show the following signs: (a) pelvic rotation; (b) extensive pa-

FIG. 4-B

FIG. 4-C

Fig. 4-B: December 8, 1941. There is a right lumbothoracic and a left high thoracic curve. The spinous processes of the first to the seventh thoracic vertebra point to the right, and the eighth thoracic to the fifth lumbar point to the left.

Fig. 4-C: December 8, 1941. Showing the relative thoracic lordosis and lumbar kyphosis.

FIG. 4-D

FIG. 4-E

Fig. 4-D: June 10, 1942. The curves and rotation have increased.

Fig. 4-E: June 10, 1942. Showing sharp lumbosacral lordotic angulation and lumbothoracic kyphosis,—both signs of sitting curves leading to pelvic obliquity.

ralysis of the abdominal muscles; (c) flail or very weak lower extremities; (d) bilateral paralysis or marked weakness of the gluteus maximus; (e) sharp lordotic angulation in the lumbosacral region; (f) lumbothoracic kyphosis (Fig. 4-E).

Flail Lower Extremities: Prevented from walking by their flail lower limbs, these children sit most of the time, bent to one side,—usually to the left. There are two reasons for the latter phenomenon. In the first place, the right upper extremity is most commonly used in writing and sewing, with the consequent bending of the trunk to the left. The second factor is the already established physiological scoliosis, which invariably shows a right convex curve in the lower thoracic segment.

Paralysis of the Glutei: Paralysis of the glutei deprives the pelvis of any stability whatsoever. In such cases, the pelvis can be bent forward with scarcely any resistance.

Paralysis of the Abdominal Muscles: The importance of abdominal paralysis in the production of pelvic obliquity has been clearly pointed out by Lowman in an important article on scoliosis. The main significance of abdominal paralysis can be best shown with reference to the sitting position. The normal individual and even paralytics with good abdominal muscles sit with fairly erect trunks and slight lumbar kyphosis. In patients with seriously damaged abdominal muscles, the pelvis tilts forward, causing a sharp, short, sacrolumbar lordotic angulation. The adjacent superior segment of the spine sags and collapses in kyphosis. The reason for the sagging is the almost unlimited relaxation of the ligamentous apparatus, and, for the kyphosis, the sitting position. The disturbed, uncoordinated abdominal respiration increases the imbalance of the spine (see later). A sagging lumbothoracic spine, subject to gravitation, discloses a high degree of lumbothoracic kyphosis. In this way, the lumbar spine is deprived of its main protection against lateral deviation—lumbar lordosis—and becomes powerless against asymmetric forces.

FIG. 4-F

Note the forward rotation of the left shoulder of the patient in sitting position.

The pelvic obliquity is initiated by the sitting position, but its full development is greatly favored by the gait. The pelvis twists and tilts, the trunk suddenly and vehemently bends forward-lateralward at the hip at every step, while the body tries to save its balance which is threatened by the insufficiency of the glutei. *The dynamic factor of the*

FIG. 5-A

FIG. 5-B

K. Y. (No. 290), female, aged fourteen years. Roentgenograms show concave rotation,—a regular temporary phenomenon in paralytic scoliosis.

Fig. 5-A: August 27, 1941. The lumbar vertebrae are rotated to the right, with the lumbar curve pointing to the left.

Fig. 5-B: January 31, 1942. The lumbar curve is now pointing to the right, and the lumbar vertebrae are rotated to the right,—convex rotation and the final curve.

human gait, imposed on the rotated and imbalanced paralytic spine, is the main scoliosing force in all types of paralytic scoliosis; as in normals, it is the cause of the physiological scoliosis. Although in patients with paralysis the spine alternately bends and stretches during gait, the emphasis, unfortunately, is more on the bending phase, even when the use of crutches takes care of the safety of the erect position, and fails to compel the trunk to bend compensatorily to the other side when the step changes.

Pelvic Rotation: Pelvic rotation, in most instances present while the patient is still in the supine position, paves the way for lateral deviation. Pelvic rotation renders the position of the spine asymmetric from the start.

Whether, and how far, the asymmetric involvement of the abdominal muscles influences the development of the lateral curve is hard to say. Shortening of the abdominal muscles and of the quadratus lumborum (Lowman, and Mayer) seems to follow the development of scoliosis.

The upper portions of the spine usually react to the formation of sitting curves in the following manner: A sagging, unstable trunk, bent to one side, has to be balanced in some way; otherwise the patient might turn over on one side and would hardly be able to use his arms. There-

fore, the upper parts of the thoracic spine bend to the opposite side. The consequence is a high thoracic shoulder curve, the spinous processes of which show rotation to the right. In this way, another curve of thoracic type develops with spinous processes pointing in two opposite directions. These counter curves, however, are regularly very short and their rotation, though sometimes of considerable amount, does not extend lower than the fifth thoracic vertebra. There are many exceptions to this rule, showing rotations extending as low as the eighth thoracic vertebra. That they are sitting curves can be easily established by consulting the aforementioned signs.

The type of lateral curves following pelvic rotation cannot be predicted with certainty. The resistance and behavior of the thorax, the muscle imbalance, breathing, exercises, the manner and duration of sitting and walking, etc., all have a part to play in the production of the curvature. However, in the majority of cases, the final curve is a long lumbothoracic or total curve. In our Early Series, the lumbothoracic and total curves combined amounted to 76 per cent. and, in the Late Series, to 92 per cent. of all curves caused by pelvic rotation.

It is a highly significant feature of paralytic scoliotic curves that they, at least for a period, represent the phenomenon so much discussed at the beginning of the century: concave rotation (Schulthess). (See Figures 5-A and 5-B.) This means that the vertebrae rotate toward the concavity, the spinous processes thus pointing toward the convexity of the curve. Our survey on paralytic scoliosis has shown an almost regular appearance of concave rotation as a temporary stage. However, the concave rotation never lasts; it disappears after a period of several weeks or months. Thus concave rotation always signifies that we are dealing with a temporary feature. *The final curve always shows convex rotation; this is the only rigid rule thus far presented in the pathology of scoliosis.*

Rotation of the Thorax

The rotation of the thorax is an essential phenomenon of any scoliosis, irrespective of its etiology (Figs. 6-A, 6-B, and 6-C). *Thoracic rotation is the only physiological motion which is capable of producing all signs of scoliosis in the thorax, as the author has proved in previous papers.* Accompanying rotation of the thorax, lateral deviation of the spine invariably appears in the physiological experiment as well as in the majority of curves originating in thoracic rotation. Lovett also stressed this fact.

The rotation of the thorax has an effect of paramount pathological importance. Rotation of the ribs, which are firmly connected with the transverse processes, cannot remain localized, but is transmitted simultaneously to the vertebral arch. This means that the transverse processes are subject to a force pushing them toward the concavity (to the left side in the example shown in Figure 6-A). Consequently, the transverse processes receive a rotary impulse toward the concave side of the curve, imposing on the vertebral bodies a rotation to the opposite side (in our

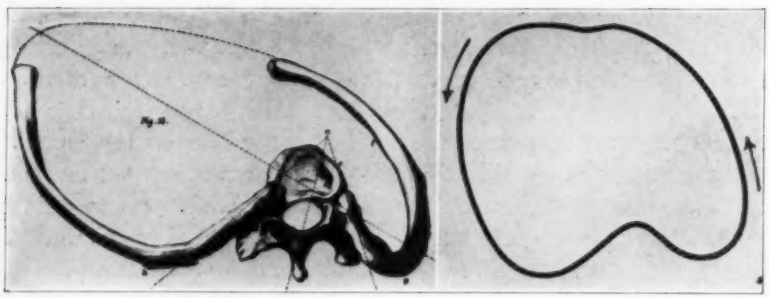

FIG. 6-A FIG. 6-B

Fig. 6-A: Rib ring from a patient with habitual scoliosis. Notice the narrowing of the right side and the enlarging of the left; the prominence on the right side of the back and the left side of the front. The vertebral end of the rib, pressing on the transverse process of the vertebra, pushes the arch to the left and the vertebral body to the right. [*Reproduced from Taf. IV, Fig. 16, in Pathologie und Therapie der seitlichen Rückgrat-verkrummüngen (Scoliosis) von Adolf Lorenz. Wien, Alfred Hölder, 1886.*]

FIG. 6-C

Fig. 6-B: Cross section of a normal thorax rotated to the left. Notice that all the signs shown by the scoliotic rib ring are present. [*Reproduced from Über Bedingungen und auslösende Momente bei der Skoliosenentstehung (Versuch einer funktionellen Skoliosenlehre) von Aladár Farkas. Stuttgart, Ferdinand Enke, 1925.*]

Fig. 6-C: A leather and wood model of the spine demonstrates the effect on the spine and thorax of rotation of the thorax to the left. Thoracic rings are similar to those in Figures 6-A and 6-B. The thoracic vertebral arch is pushed to the left, and the spinous processes point to the left. The lumbar spine is rotating in the same direction as the thorax,—to the left. The lumbar spinous processes point to the right, as there are no ribs to push them in an opposite direction.

example to the right side). *As eventually the side toward which the vertebral bodies have rotated will become the convex side, we speak of convex rotation of the vertebrae.* This is the reason that the thoracic vertebrae carry out a rotation the direction of which is opposite to that of the rotation of the thorax. One can easily understand this paradoxical phenomenon by visualizing that during rotation of the thorax the convex side undergoes considerable compression exerted by muscle pull and pressure (Fig. 6-B).

How does the lower part of the thorax with its floating ribs and the lumbar spine react to the rotation of the thorax? As the floating short ribs are not capable of exerting any considerable pressure on the transverse processes and the lumbar spine has no ribs at all, the lower thoracic spine and the entire lumbar spine will follow the rotary tendency initiated by the thorax. Hence the lumbar spine and the lumbothoracic region will rotate in the same direction as does the thorax (in our example from the right to the left). Consequently, the vertebrae from the eleventh

FIG. 7-A

FIG. 7-B

Final form of paralytic scoliotic curves in two patients more than five years after the onset.

Fig. 7-A: F. F. (No. 468), female, fifteen years of age. In the thoracic type of curve, the spinous processes of the fourth to the tenth thoracic vertebra point to the left, and those of the eleventh thoracic to the fifth lumbar, to the right.

Fig. 7-B: D. F. (No. 467), female, twenty years of age. In the pelvic type of curve, the spinous processes of the fourth thoracic to the fifth lumbar vertebra point to the left.

thoracic to the fifth lumbar will rotate to the left,—that is, the spinous processes will point to the right. *Thus in thoracic rotation the vertebrae rotate in two directions (in the case illustrated in Figure 7-A, the thoracic vertebrae rotate to the right and the lumbar vertebrae to the left); while pelvic rotation leaves the spine with vertebrae rotated in one direction* (Fig. 7-B).

According to our statistics in the Late Series, 30 per cent. of the paralytic curves were derived from thoracic rotation and 70 per cent. from pelvic rotation. This is not surprising when we take into account the fact that the mechanical cause of pelvic rotation is the imbalance of the more frequently involved lower extremity.

In many cases, thoracic rotation seems to be a combination of pelvic and thoracic rotation. Frequently, even, it is the pelvis which initiates the rotation and the thorax which follows.* This explains why in our Early Series the curves originating from thoracic rotation amounted to 23 per cent. of all paralytic curves, while in the Late Series, 30 per cent. of the

* In such cases, however, the rotation never extends high into the thoracic spine and never is of great amount even in the lower portions of the thoracic spine, in contrast to the cases of pure pelvic rotation of permanent nature.

curves were caused by thoracic rotation. Therefore, we assume that in many cases the pelvis is the initiating factor in the rotation, but the thorax, following the rotary tendency, seems to outdo the pelvis, finally producing true thoracic curves.

Thoracic rotation has two main causes: (1) imbalance of the upper extremity, especially the displacement of the scapula; (2) impaired respiration. Thoracic rotation requires a double curve for the final establishment of scoliosis, in order to meet the requirements of convex rotation. Our statistics show double curves originating in thoracic rotation in 82.5 per cent. of the Early Series and in 91 per cent. of the Late Series.

FIG. 8-A

FIG. 8-B

R. L. (No. 203). Respiratory curve in a male, aged nine years, who had had involvement of the muscles of the right shoulder and the intercostal muscles, with a quick recovery of the shoulder muscles.

Fig. 8-A: April 16, 1940. In the supine position, the spinous processes of the first to the eighth thoracic vertebrae point to the left, and those of the ninth thoracic to the fifth lumbar, to the right.

Fig. 8-B: December 23, 1940. In the standing position, note the expiratory descent of the ribs characteristic of respiratory curves. There is a high thoracic curve to the right, with a lumbothoracic curve of thoracic type to the left.

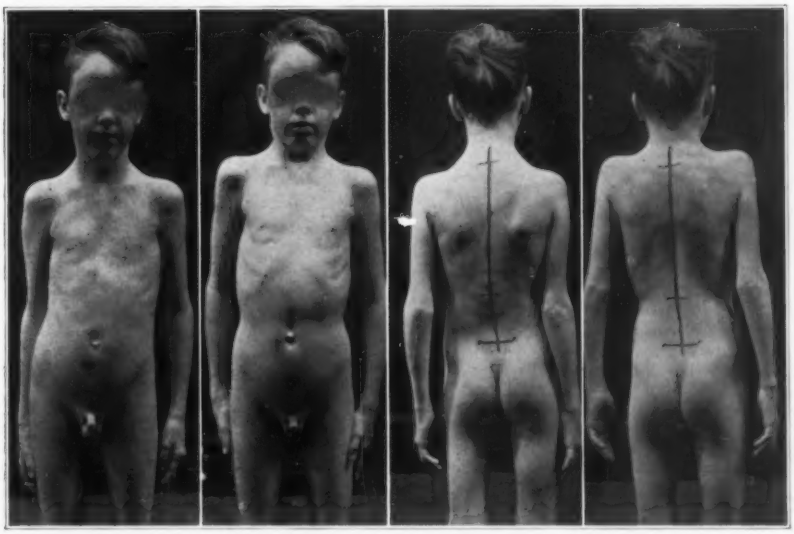

FIG. 8-C FIG. 8-D FIG. 8-E FIG. 8-F

Fig. 8-C: On expiration, the thorax is rotated to the left and bulges on the left.

Fig. 8-D: On inspiration, the thorax is rotated to the right; the bulging and asymmetry have disappeared. The right shoulder is higher; the neck is enlarged; and the shoulder girdle is pulled up: the auxiliary inspiratory muscles are at work.

Fig. 8-E: On expiration, as seen from the back, there is a lumbothoracic curve to the left, with a lumbar kyphosis.

Fig. 8-F: On inspiration, the lateral deviation is corrected, and the lumbar spine is in lordosis.

Rotation of Shoulder

In a smaller percentage of cases, we encounter rotation of the shoulder without displacement of the scapula as the starting point of paralytic curves. In normal persons, the rotation of the shoulder rotates the uppermost four or five thoracic vertebrae only, but in patients with paralytic spines, this may be different. *If the rotation of the shoulder is connected with a respiratory disturbance, it can extend as low as the fifth lumbar vertebra, producing true thoracic curves with rapid progress and collapse of the spine* (Figs. 8-A through 8-F). True shoulder curves restricted to the first four thoracic vertebrae are encountered in isolated deltoid paralysis of the arm. They show the spinous processes of these vertebrae pointing toward the healthy side.

Respiration

A discussion of this factor will be found in a later section of the paper.

MORPHOLOGICAL CHANGES IN SPINE AFTER ONSET OF INFANTILE PARALYSIS

Now two questions arise:

What is the reason that this rather rigid organ, the spine, with its

FIG. 9-A

FIG. 9-B

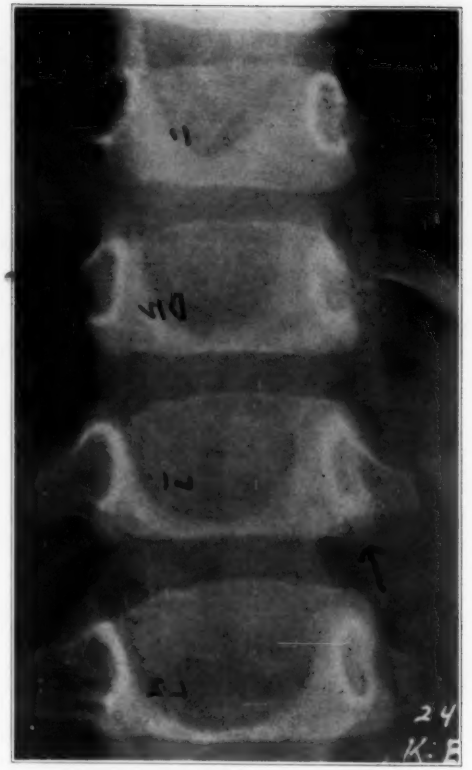

FIG. 9-C

K. B. (No. 242), female, aged four years, had slight involvement of the left lower extremity.
Fig. 9-A: March 17, 1941. In the supine position, the pelvis is rotated to the right.
Fig. 9-B: May 31, 1941. Standing, there is a right lumbar curve.
Fig. 9-C: The appearance of the ossification centers is shown at the inferior vertebral edges.

highly reliable antirotary system of discs and ligaments, has given way? How does the described rotation become possible?

The factors of the passive protective system which save the normal spine from the permanent rotation and lateral deviation involved in infantile paralysis are the discs and the ligamentous apparatus. Our findings on the latter structures are based on roentgenographic examinations.

A few weeks after the onset of the disease, the *paralytic spine* develops, disclosing characteristic changes. These changes apparently occur regardless of the parts involved and independent of the severity of the attack.

In the majority of the cases, the intervertebral spaces become enlarged, as though the discs have undergone quilling.

Following this stage, the entire spine becomes cloudy and hazy, as though covered with a veil (Figs. 3-A and 3-B). The borders between the vertebrae and the intervertebral spaces become less marked, sometimes noticeably effaced. This holds true especially for the thoracic spine, but the lumbar spine is not spared. This second stage may last for years, but meanwhile the third stage begins, often very soon after the start of the second stage. The cloudiness may or may not disappear, and a marked bone atrophy sets in. This process affects the entire spine from the first thoracic to the fifth lumbar vertebra. The intervertebral spaces are markedly narrowed, irregular, and uneven.

A single irregular space may frequently run in a zig-zag line, studded with pearl-like impressions. Regularly, the spaces between the eleventh and twelfth thoracic and the twelfth and first lumbar vertebrae are narrower than the rest and the discs seem to overlap the lateral edges of the vertebrae, as though extruded from the spaces, and showing later on numerous calcium deposits. In this stage, the borders of the long spinal ligaments also become visible. In any case, general atrophy of the spine ensues after a shorter or longer period. *This atrophy is universal, extends over the entire spine, and is of about the same density. This is an important feature of the paralytic spine, as it enables us to differentiate between paralytic scoliosis and scoliosis of any other etiology.* In the majority of cases of habitual scoliosis, only a few vertebrae are markedly atrophic. Sometimes only one vertebra is atrophic,—that in the center of the curve.

Besides these general features, there are specific signs disclosing a rather serious process going on in the whole bone-disc apparatus. The early and disturbed ossification of the epiphyseal ring is one of the first of these features. On the roentgenogram, the normal ossification of the epiphyseal ring appears in girls between the ages of eleven and fourteen; in boys, between thirteen and sixteen (Hanson). In paralytic spines we rarely miss the appearance of ossification centers even at the age of four (Fig. 9-C). The ossification centers are usually not of the well-known hairlike appearance; they are rather bulky, irregular, and jump from one vertebra to the other. Very soon, they penetrate the intervertebral spaces and are suggestive of bulky, sharply defined, or confluent calcium depos-

FIG. 10-A

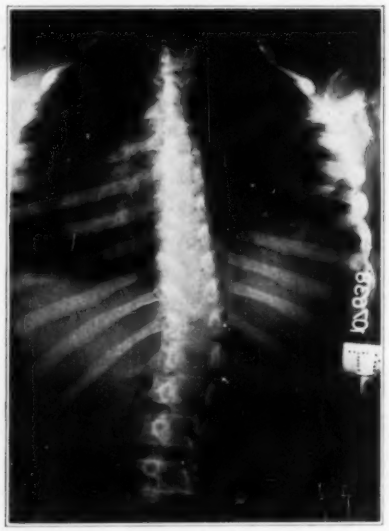

FIG. 10-B

B. D. (No. 414). July 3, 1940. Female, aged six years.
Fig. 10-A: In the supine position.
Fig. 10-B: In the standing position, the twelfth thoracic vertebra has shifted to the right, while the disc has become maximally compressed. In the backward tilting of the entire thoracic spine, the intervertebral spaces are hardly recognizable. The paralytic spine appears as a confluent whitish mass. Note the concave rotation in the lumbar spine.

FIG. 10-C

FIG. 10-D

Fig. 10-C: The lumbar spine in the supine position shows what are presumably calcium deposits in the disc, protruding to the side.
Fig. 10-D: In the standing position, the enlarged vertebrae show pelvic rotation to the left with the spinous processes pointing to the right. There is a right lumbothoracic curve.

its all along the intervertebral spaces. This irregular, early, excessive ossification of the epiphyseal ring is one of the chief features of the paralytic spine.

The entire intervertebral space is sometimes filled with minute calcium deposits, which later may become confluent or even disappear. In a number of cases, a restitution may start, and the vertebrae and intervertebral spaces resume their normal appearances after a while.

During the process the intervertebral spaces appear much narrower in the standing position than in the supine, but in the latter position also marked narrowing is revealed when compared with previous pictures. This stage represents the fourth stage of the disease of the discs,—the stage of compression. The physiologically solid and resistant disc-bone system has undergone a profound change. Its mobility is increased to such an extent that the vertebrae are able to perform univertebral or plurivertebral motions, which no normal disc system would allow. Therefore, it is comprehensible that *the scoliotic curve may change the side of its convexity several times in the course of five years; also, the side of rotation frequently changes.*

The paralytic spine shows remarkable mobility and flexibility characterized by:

a. *Forward-backward tilting* between two vertebrae or in an entire segment. This motion is so exaggerated that one may observe the superior borders of the backward-tilted vertebrae and the cartilaginous plate, which sometimes shows proliferation; in many instances, the whole spine appears as a confluent whitish mass without border lines between the vertebrae (Fig. 10-B).

b. *Translatory shift.* The vertebrae are capable of slipping on one another to the side (Fig. 10-B). A single vertebra or an entire segment may shift to the side, compressing the underlying discs.

c. *Unilateral compression.* This is a characteristic feature of scoliosis.

d. *Vertebral rotation.* This is the most important sign of increased spinal mobility.

Calcium deposits appear frequently in the form of calcinosis intervertebralis (Figs. 11-A and 11-B). Calvé and Galland reported this condition in 1922, and it has since been observed in but a handful of cases, only one of them, described by Báron, being in a patient under thirty years of age (Bársony and Koppenstein). *Compression, flexibility, rotation, early appearance of the epiphyses, disturbed ossification, and calcification are the signs of infantile paralysis of the spine.*

These phenomena are, according to all probability, early signs of a particular degenerative process of the intervertebral discs. This degenerative process may proceed and later on assume well-known pathological forms (Beadle, Schmorl, and Holman and Duff). Narrowing of the intervertebral spaces, Schmorl's pearls, appearances suggestive of Scheuermann's disease (Fig. 12-B), and even powerful osteophyte production

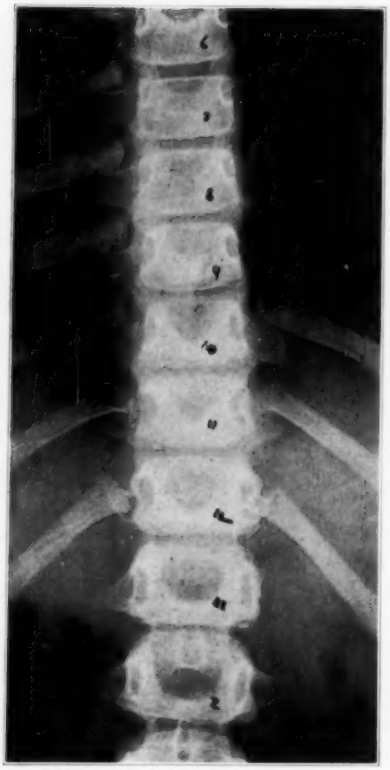

FIG. 11-A

FIG. 11-B

C. C. (No. 293). January 16, 1942. Female, aged five and one-quarter years, had involvement of the neck and right shoulder. The latter has completely recovered.

Fig. 11-A: Ossification is progressing, and there is calcification in many intervertebral spaces.

Fig. 11-B: In the lateral view there is calcinosis in some of the intervertebral spaces.

may be observed. On the other hand, the early changes of the intervertebral discs seem to be reversible. Even after several years' duration we have seen discs consolidate and regain their sharp borders, and the intervertebral spaces appear dark and translucent; at the same time the vertebrae are recovering from atrophy (Figs. 13-E and 13-F). This probably means that the changes in the discs derive from the same source as the atrophy of the bone.

There is one feature of the flexible paralytic spine which appears with a surprising regularity during the flourishing stages of disease of the discs. This is the slight or marked thoracic lordosis and lumbar kyphosis which is present or even increased in the standing position. *Besides the appearance of larger, more even, and well-defined intervertebral spaces, the healing of the discs, and, in many instances, the simultaneous improvement of paralytic scoliosis, is manifested by the disappearance of the general cloudiness, improvement of bone atrophy, diminishment of rotation and of compression*

of the discs, and, finally, by the re-establishment of thoracic kyphosis and lumbar lordosis.

RÔLE OF MUSCLE INVOLVEMENT

What is the rôle of muscle paralysis, called muscle involvement, in the initial and final rotation and in the production of lateral deviation?

In spite of the great variety of changes characteristic of the paralytic spine, there cannot be any doubt about the decisive rôle of muscle imbalance in the production of rotation and scoliotic deformation. The rôle of muscle imbalance is best characterized by the fact that the majority of cases of paralytic scoliosis exhibiting self correction also show a complete return of muscle balance. *Without muscle imbalance, respiratory disturbance, or both, no paralytic scoliosis is possible. On the other hand, muscle imbalance itself is not capable of producing scoliosis of any severity without involvement of*

FIG. 12-A

FIG. 12-B

H. C. (No. 471). December 29, 1941. Male, aged sixteen years, had complete return of muscle power after five years.

Fig. 12-A: The pelvis is rotated to the right, and the spinous processes point to the left. The intervertebral spaces are compressed and uneven, and are filled with calcium deposits. There is a right lumbothoracic curve.

Fig. 12-B: In the lateral view, all the intervertebral spaces are markedly narrowed, uneven, and show signs of degeneration. They suggest Scheuermann's disease.

Fig. 13-A

Fig. 13-B

Fig. 13-C

H. W. (No. 410), female, aged six years, had slight involvement of both lower extremities and of the abdominal muscles. Later on, there was complete recovery, except that the right leg was one and one-half inches shorter than the left.

Fig. 13-A: August 3, 1937. Cloudiness and atrophy are noted all along the spine, and slight rotation of all spinous processes to the right.

Fig. 13-B: December 13, 1937. Rotation has increased. The intervertebral spaces are uneven, with calcification between the eleventh and twelfth thoracic vertebrae. There are slight left thoracic and right lumbothoracic curves.

Fig. 13-C: July 6, 1938. The curve has changed into a right thoracic curve.

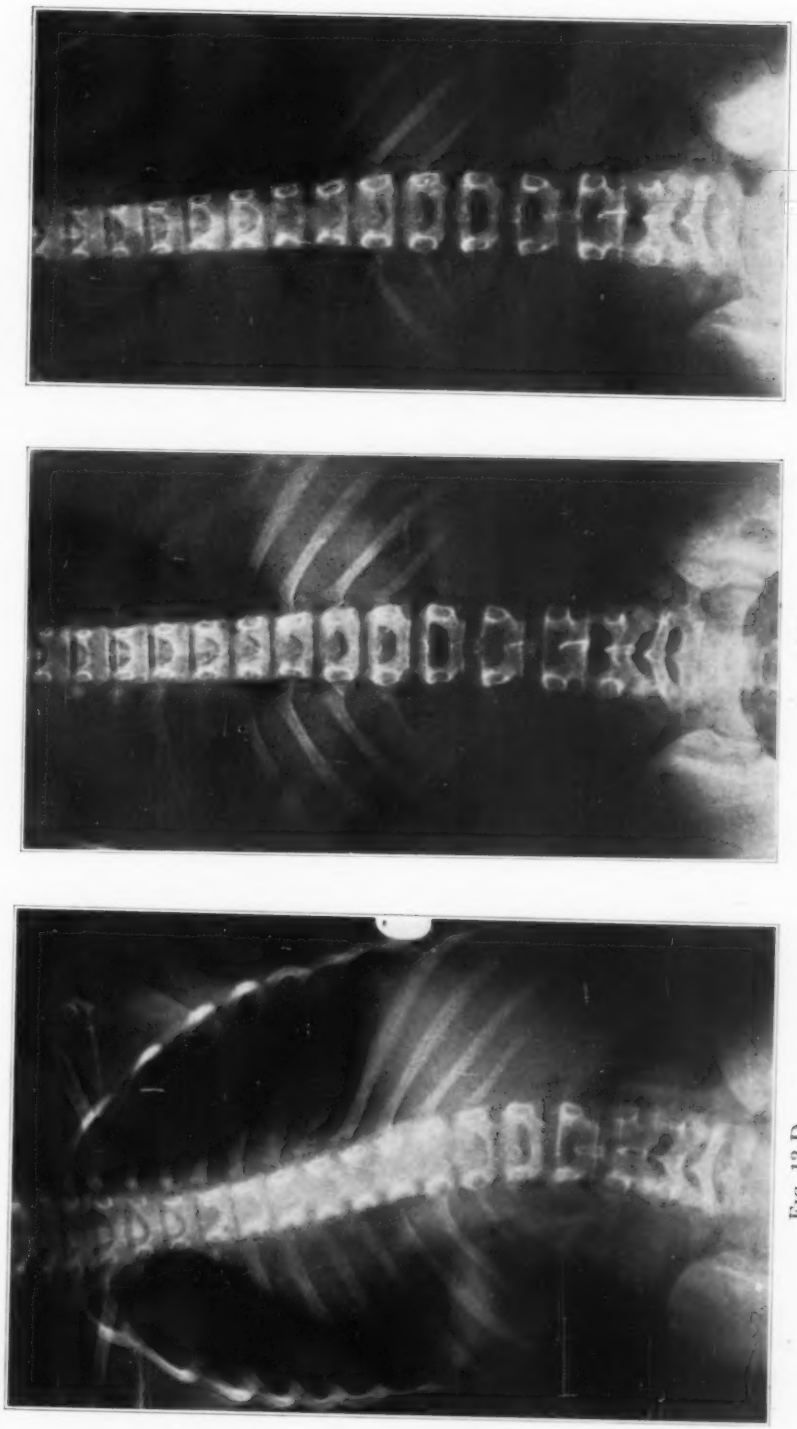

FIG. 13-D

FIG. 13-E

FIG. 13-F

Fig. 13-D: April 6, 1939. All spinous processes have rotated to the left, and there is a long right lumbothoracic curve. The vertebrae are tilted backward, and the intervertebral spaces are effaced and cloudy.

Fig. 13-E and Fig. 13-F: February 24, 1941. In both the supine and standing positions, there is complete restoration of the intervertebral spaces, and no atrophy is present. There is a very slight curve to the right in the lumbothoracic segment.

the passive protective apparatus,—that is, the disc-ligamentous system.* The latter occurs very rarely in infantile paralysis; such involvement is usually seen in individuals who have contracted poliomyelitis after puberty.

In speaking of the imbalance of the human body, one has to distinguish between *physiological* and *pathological imbalance*.

Physiological imbalance is represented by right-handedness, by the greater weight of the right side, by the more powerful muscles of the right side, and by the left-sided situation of the heart and the great vessels. The French literature (Dieulafé) significantly speaks of the "right and left man" (*l'homme droit et l'homme gauche*), emphasizing the fact that the right and left sides of the body in most functions of everyday life are acting separately and alternately. The functions between the "right and left man" consist of a *symmetrically alternating imbalance*.

Hence, if any kind of acquired imbalance, as in infantile paralysis, is added to the physiological imbalance, the latter is more efficiently at work than normally. *The conspicuous predominance of the right convex thoracic curves in paralytic scoliosis is one of the consequences of physiological imbalance*. The symmetrically alternating asymmetry, as the gait exerted on a passive protective system whose resistance is greatly reduced, is not only the chief cause of the lateral deviation, but seems to be one of the main reasons for the predominance of the right convex thoracic, left convex lumbar curves.

In our Early Series, 79 per cent. of the curves of thoracic origin were found to be right thoracic, left lumbar, and in the Late Series, 96 per cent. were of the same type.

Also there was a predominance in the production of the right convex thoracolumbar and total curves in the Early Series (66 per cent.), as well as in the Late Series (75 per cent.).

Thus far, orthopaedic literature has tried to find an explanation for paralytic scoliosis by blaming the direct pull of the healthier muscles or the paralyzed ones in the state of fibrous shortening for the lateral deviation.

The discussion of the paralytic spine has revealed that we have been dealing with a spine whose passive protective system has lost much of its resistance. Furthermore, it is apparent that rotation is the initial and outstanding feature of paralytic scoliosis. The disclosure of the factors causing rotation leads to a far better conception of the estimation of the rôle of muscle involvement. Instead of thinking in terms of individual muscles or groups of muscles it would be better to adapt our thinking to the consideration of two alternately functioning sides of the body. *The rotation of the spine is nothing but the predominance of one function instead of the usual alternating functions.*

As stated in the preliminary remarks, the spine has no motions by itself; it is subject to the motions of its master organs—the pelvis, thorax,

* This fact seems to be the reason why congenital defects of the muscles, congenital hemiplegias, hereditary or acquired progressive muscular dystrophies even of the spinal form (Duchenne-Aran), and unilateral congenital dislocations of the hip with conspicuous muscle imbalance are regularly not accompanied by scoliosis.

shoulder girdle, and head—and of the respiration. Principally during gait and sitting, *the reduced resistance of the passive protective system (ligamentous apparatus), plus the disturbed balance of the master organs of the spine and the disturbed respiration bring about the scoliotic deformation in infantile paralysis. As long as the patient lies in bed dispensing with gait and sitting, no scoliosis develops, which proves the correctness of the conception advanced.*

CURVES ORIGINATING IN THORACIC ROTATION

Thoracic curves originate from: (a) primarily pelvic curves; (b) imbalance of the shoulder girdle; and (c) disturbance of respiration.

The mechanics of the curves originating from primarily pelvic curves has been discussed earlier in this paper.

Most thoracic curves originate in the imbalance of the upper extremities, especially of the shoulder girdles; the upper extremities play the same part in the production of thoracic curves as does the pelvis in the production of pelvic curves. Also, the shoulder girdle has its alternating rotation during locomotion. In the sitting position, while the necessary performances of everyday life are accomplished, the upper extremity acquires the lead. However, it is far from possessing the rigid rhythm of gait or the automatic alternation of the legs. Human beings really are bipedal and one-handed. The imbalance of the shoulder girdle is thus of a partly different nature from that of the lower extremity.

How does the shoulder girdle react to the impairment of its functions by extensive paralysis? After the muscles of the shoulder girdle have lost their tonus, and the ligaments have sustained a reduction of tension, the weight of the shoulder and arm is suddenly felt. Carrying loads on the shoulders is connected with the elevation of the shoulder, which seems to be one of the few deeply rooted automatic functions that the upper extremity possesses. Hence, elevation of the paralyzed shoulder invariably occurs in shoulder-girdle paralysis.

It is necessary to distinguish between the paralysis of: (1) the deltoids alone, and (2) the paralysis of the specific muscles of the scapula. Our survey of patients with isolated deltoid paralysis, alone, or combined with the paralysis of the forearm and hand, has shown that in such cases usually no scoliosis occurred. However, the paralysis or paresis of the specific muscles of the scapula, such as the trapezius, rhomboidei, latissimus dorsi, and serratus anterior is regularly followed by scoliosis of the thoracic type. Lasting rotation of the shoulder and of the thorax almost invariably ensues after the scapula has lost its well-controlled, stable position. The scapula is the center around which the coordinated function of the arm takes place, so whenever the scapula loses its muscle control and becomes displaced, slipping aimlessly up and down the chest wall and rotating around strange axes, *the upper extremity and the shoulder girdle abandon the functionally vital frontal plane and assume diagonal positions by a permanent rotation.* In some cases a paradoxical phenome-

non occurs. The arm, which in abductor paresis alone has very little active abduction, in combined abductor and scapular paresis with preservation of the serratus anterior, is capable of active abduction of greater or lesser amount. The middle and inferior portions of the trapezius and the rhomboidei give way, the scapula descends and pulls farther from the spine, and the serratus anterior rotates the scapula around its lateral angle, giving the arm an abduction momentum. In his effort to achieve further abduction, the child bends the trunk maximally to the other side, causing the thorax to bulge toward the side of paralysis and the arm to slip higher; at this moment pendulum actions are performed by the forearm, elbow, and hand, the arm swings forward-sideward, and some strange type of abduction has been accomplished. The manoeuvre rotates and bends the paralytic spine, and scoliosis develops.

In all cases with right-handedness, even if the left shoulder has better muscles or is only slightly weakened, the child tries to use the right arm, thus deforming the spine.

On the convex side there is to be observed a bulging of the thorax, especially in its lower axillary aspects. The bulging increases on any attempt of the patient to abduct the arm. This bulging is caused partly by this abduction manoeuvre and partly by the expansion of the thorax as a consequence of decreased tonic pressure on the ribs following paralysis. As the ribs constitute one of the chief and the most powerful passive protective factors of the spine against lateral deviation, the spine readily penetrates into the thoracic cavity after the ribs have given way.

Paralysis of the serratus anterior is one of the most serious causes of impairment of function at the shoulder girdle. Not only does it rotate the scapula around its lateral angle, slipping sometimes as high as the second cervical vertebra, but it also has a momentous bearing on the position of the ribs, especially if respiratory disturbance is present. As Duchenne proved in his incomparable studies, if the scapular insertion of the serratus anterior is the fixed point, the muscle can elevate the ribs during inspiration. If there is a paresis of the intercostals and the serratus anterior is also paretic, there remains no muscle capable of raising the ribs directly into the inspiratory position. If at the same time, as frequently happens, the abdominal muscles are preserved to some extent, in the absence of antagonists, they pull the thorax downward and rotate it to the other side. So develop many of the thoracic curves due to shoulder paresis combined with respiratory paralysis.

There is another active factor which increases thoracic curves or even leads to them. In disturbed respiration, the auxiliary inspiratory muscles pull the shoulders high (the right side higher than the left)—physiological imbalance—and in the upward-forward tilting shoulder there develop high thoracocervical curves with thoracocervical kyphosis (Figs. 8-A, 8-B, 8-C, 8-D, 8-E, and 8-F). Combinations leading to thoracic curves seem to be innumerable. To understand and trace them all is not necessary; one has to look for the main factors which bring about

the disturbed rotary balance between the right and the left shoulder superimposed on a passive protective system with greatly reduced resistance.

In comparing pelvic and scapulohumeral imbalance, two factors should be borne in mind: High thoracic curves of the flexible paralytic spine could develop more easily than pelvic curves if it were not for the ribs, whose grip on the spine is firm; on the other hand, thoracic curves lack the static factor which always intervenes in pelvic curves. However, the rôle of shortening of one leg has been overestimated; its main importance is that it prolongs the swinging period of gait as has been pointed out. Lateral tilting of the pelvis by leg shortening hastens the fixation of scoliotic curves, but does not cause them.

RESPIRATION

The low vital capacity in thoracic curves, found by Colonna and vom Saal, was fully demonstrated by our studies. The reason for this conspicuous fact seems to be found in the physiological effect of respiration on the spine.

During inspiration, a marked distention of the discs occurs, as manifested by the enlargement of the intervertebral spaces. Normal respiration is indispensable for the health of the intervertebral discs. If the respiratory forces permanently decrease, no distention follows the constant compression, and such a system of discs is susceptible to rapid unilateral compression, due to the action of the always present asymmetric forces of the body. *Therefore, whenever the system of discs already seriously affected in the paralytic spine is deprived of the regular distention by healthy and adequate respiration, paralytic scoliosis of the most rapid and crippling sort is liable to follow.*

However, there are two other factors which open the way for the spine to penetrate the thorax. During inspiration, in addition to enlarging, the thorax (especially in its upper segment) rotates to the right (Fig. 8-D); during expiration, it rotates toward the left side (Fig. 8-C).

The rotation of the thorax does not take place in a purely horizontal plane; rather, it is performed in a horizontal-sagittal plane, forward-downward. If the inspiratory muscles are paralyzed, and the expiratory muscles (especially the lateral abdominals) are present, a downward-lateral pull is exerted on the thorax by the stronger abdominals, and a contracture develops. In conjunction with thoracic rotation, this leads to scoliosis.

The third respiratory factor is the position of the vertebral ends of the ribs. In inspiration, the vertebral ends of the ribs turn their broadest surface toward the intervertebral spaces, affording the vertebrae a great amount of protection against lateral deviation. The greater the expiratory descent of the ribs, the smaller is the rib surface covering the intervertebral spaces. In extreme expiration the spaces almost completely lose their protection, and the spine is free to penetrate the thorax.

FIG. 14-A

FIG. 14-B

FIG. 14-C

J. K. (No. 418), male, ten years of age, had a respiratory thoracic curve, with thoracic rotation. The diaphragm, the intercostal muscles, and both lower extremities were involved.

Fig. 14-A: April 23, 1937. Note the high thoracic curve to the right and the lumbothoracic curve to the left, with increased cloudiness and compression.

Fig. 14-B: November 5, 1938. The first to the seventh thoracic spinous processes point to the left; those of the eighth thoracic to the fifth lumbar vertebra, to the right. There is serious expiratory descent of the ribs. The spine is cloudy, and the intervertebral spaces are narrowed and compressed.

Fig. 14-C: June 22, 1939. The spine has collapsed, and is penetrating the thoracic cavity.

Two of the three factors—inspiratory distention of the discs and inspiratory covering of the intervertebral spaces by the ribs—are the principal obstacles which, if undisturbed, prevent the spine from penetrating the thoracic cavity.

Curves of respiratory origin can be recognized by the surprisingly great expiratory descent of the ribs (Fig. 14-A).

SECONDARY CURVES

In paralytic scoliosis, the secondary curves are, in most instances, formed simultaneously with the primary curves. Rotation influences the thoracic and the lumbar spines in varying degrees; one always lags behind, and this gives opportunity to the longitudinal muscle pressure (Feiss) and the force of gravitation to form the curve opposite the "primary" curve. This is especially the case in curves originating in pelvic rotation. In thoracic rotation the twofold rotary deviations of the vertebrae prepare the way for the formation of the secondary curve. However, as rotation precedes the deviation, the secondary-curve formation depends on many factors, such as muscle involvement, gait, sitting, exercises, treatment, etc.; so that in many cases such secondary curves are formed in which the original rotation appears as concave rotation. Ortho-optical requirements form sharp, short curves above long pelvic curves. Pelvic curves without secondary curves are much more common than thoracic curves without them. Sometimes years are required for thoracic curves, even of the respiratory type, to bring about lumbar curves with opposite vertebral rotation, if there is also present a pelvic rotation opposite to the rotation of the thorax.

PROGNOSIS

The prognosis depends on: (a) the severity and duration of the involvement of the discs and ligaments; (b) the degree of muscle imbalance; (c) the rotary origin of the curve; and (d) the age of the patient.

It is not the severity of the involvement or the muscles involved, which ranks first in importance, but the manner of locomotion caused by the extent of imbalance. If the patient is capable of locomotion without crutches and is willing to walk instead of sitting constantly, the prognosis of simple pelvic curves is better.

The prognosis of curves originating in pelvic rotation is better than that of curves originating from thoracic rotation, except in the case of the sitting curves. The better prognosis of pelvic curves is explained by the fact that during locomotion an alternation in the direction of pelvic rotation is always present. Locomotion invariably relieves the pelvic rotation for the period during which the other leg is swinging. Therefore, fixation of pelvic curves by constant sitting not only accumulates the pressure on one side but it also deprives the pelvis of the opportunity of relief by an opposite rotation during locomotion, which, even if it happens in an unsatisfactory manner, is one of the chief factors of self-correction.

After puberty, rotation without much curve frequently is observed.

After the age of sixteen no thoracic rotation could be observed in our Early Series.

TREATMENT

The nutritional-positional treatment, followed by a new method of muscle re-education, has been attempted. If we succeed in healing the discs in paralytic scoliosis—and we have some indication to believe we shall do so—we shall have been dealing with a purely static condition of the spine, even if we have failed to bring about a complete return of muscle power. Steindler has recently written on this subject.

Our survey on fusion disclosed that only the cases originating in pelvic rotation showed improvement or no increase in the curves after fusion. In no case originating from thoracic rotation has fusion led to satisfactory results.

We also observed cases originating from pelvic rotation, with a sitting curve, in which fusion was followed by collapse.

It must be emphasized that both treatment and prognosis are influenced to a great extent by the process of ossification at puberty,—whether it takes place on time or prematurely, depriving the vertebrae of much of their resistance.

SUMMARY

A few weeks or months after the onset of infantile paralysis, the spine discloses changes representing a pathological entity,—*the paralytic spine.* This process can be subdivided into several stages characterized by (1) morphological and (2) functional signs.

1. At the onset we observe enlargement of the intervertebral spaces, followed later on by dullness and cloudiness; the border lines between discs and vertebrae are effaced; and the spaces themselves become uneven and appear markedly narrowed. Ossification of the epiphyseal ring starts in some cases as early as the age of four; the process is very irregular, and the ossification is bulky and confluent. Minute or larger calcium deposits appear in the intervertebral spaces. This process may last for years, accompanied by general bone atrophy; in many cases after a couple of years the process apparently heals spontaneously.

2. Functionally, the paralytic spine is characterized by a high degree of flexibility and compressibility. Because of the increased mobility, univertebral or segmental rotations appear first without any lateral deviation. Due to the flexibility, forward-backward tilting of one or more vertebrae occurs with the disappearance of thoracic kyphosis and lumbar lordosis. As a result of the increased mobility and compressibility—the prime factor in the formation of scoliosis—a *translatory shift* of the vertebrae appears.

The paralytic spine is the pathological condition preceding paralytic scoliosis. The scoliotic curve requires usually from four to five years before reaching its final form. Prior to this, the side of the convexity

and the direction of the rotation may change several times. The rotation and compression of the spine are the chief factors in preparing the way for paralytic scoliosis.

The rotation is brought about by faulty mechanics of: (a) the pelvis (pelvic rotation); (b) the thorax and shoulder girdle (thoracic rotation); and (c) the respiration.

In pelvic rotation, all spinous processes point to the same side of the body. In thoracic rotation, the thoracic and the lumbar spinous processes point in opposite directions.

The cause of rotation is the *pathological imbalance* between the two sides of the body in carrying out rotary motions of different degrees during the performance of the daily routine, *especially during locomotion. The physiological imbalance,* present in every human being, takes advantage of the decreased resistance of the rotary system of the spine—that is, damage of the discs—and causes the predominance of the right thoracic, left lumbar curves.

Paralytic scoliosis is brought about by the imbalance between the two sides of the body exerted on the paralytic spine. Paralytic scoliosis can be differentiated from scoliosis of any other etiology by the uniform density of the spine in the roentgenogram, by the excessive and early rotation of the vertebrae, and by the temporary concave rotation.

Curves resulting from pelvic rotation, except for the sitting curves, have a far better prognosis than the thoracic curves, especially if the latter are associated with respiratory disturbances.

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THE ETIOLOGY OF THE UNDESCENDED SCAPULA AND RELATED SYNDROMES *

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Never before has the etiology of malformations had such practical bearing as today, when certain states maintain the right to sterilize their citizens affected by hereditary diseases and deformities. It may therefore be opportune to reconsider the present views on the etiology of a group of deformities, in the light of a newer conception which was described recently under the name of the "bleb theory" [13], and which has been offered as an explanation of the developmental mechanism of a group of multiple malformations. This theory has since been confirmed independently by Keith with regard to other deformities. The view was expressed that, if multiple deformities can be explained satisfactorily by the bleb theory, there is no reason why single deformities should not find explanation on the same basis [13]. Club-foot, congenital dislocation of the hip, undescended scapula, cleft palate, spina bifida, and other dysunions were specially mentioned.

It is the purpose of this paper to widen the circle of the "bleb diseases", and to show that the undescended scapula and allied conditions are members of the same family. However, let us first consider briefly whether present views offer a satisfactory explanation for the morphogenesis of this group. Generally speaking, it may be said that, while in former years there was a tendency to explain deformities on an exogenous basis—pressure by the womb or amnion—the opinion has shifted in the last years toward the endogenous theory,—namely, that the primary cause of deformities is an inherent quality of the embryo itself. That the exogenous mechanistic theory is, nevertheless, still accepted for the undescended scapula is probably due to two facts: first, the shoulder blade descends from a higher level to its final place; and second, it is accessible to external injuries because of its superficial anatomical position. One can easily imagine a mechanism preventing the normal descent of a superficial structure. These views are expressed by Horwitz in one of the most comprehensive studies on the subject, based on the previous literature, as follows:

"Our theory for the elevated scapula is:

1. That it is a failure of descent caused by

(*a*) Too great intra-uterine pressure, due either to an increased or diminished amount of amniotic fluid,

(*b*) Abnormal articulations of the scapula with the vertebral column,

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(*c*) A defective musculature unable to draw the scapula caudally, where neither (*a*) nor (*b*) exists,

(*d*) A normal musculature unable to draw the scapula caudally where either (*a*) or (*b*) exists;

2. That the changes in the shape and size of the scapula are an arrest of development due to improper or defective muscle tension."

Heredity, says Horwitz, plays no part in this deformity. Since 1908, when these views were formulated, very little has been added to our knowledge.

The mechanistic theory does not explain in a satisfactory way why the musculature of the shoulder region should be defective, and why abnormal articulations of the scapula with the vertebral column should exist. It certainly does not explain why 67 per cent. of the 136 cases collected by Horwitz showed some attendant defects in other parts of the body. Some of these should be mentioned here:

	No. of Cases	
Defective ribs and vertebrae	22	(16 per cent.)
Shortening of the humerus	18	(13 per cent.)
Shortening or malformation of the clavicle	22	(16 per cent.)
Talipes equinovarus	3	
Pes valgus	3	
Hallux valgus	1	
Shortening of the femur	1	
Shortening of the leg and foot	1	
Congenital dislocation of the hip	2	
Defect of the hand and fingers	2	
Radial defect	2	
Dislocation of the radial head	2	
Maldevelopment of the whole upper extremity	2	
Bifid ear	1	
Cleft palate	1	
Extremely arched palate	2	
Adenoid vegetation	3	
Strabismus convergence	3	
Hypoplasia of the mamma	1	
Supernumerary mamma	1	
Subcostal tumor	1	
Displacement of the heart to the right	2	
Floating kidney	1	
Congenital inguinal hernia	2	
Anal ectopy with incomplete atresia	1	

Horwitz, himself, admits that 67 per cent. of concomitant deformities is too high a percentage to be ignored, and suggests, "there is some *general disturbance* in which the scapula participates".

The statement of Horwitz, which again expresses a general opinion, that heredity has no part in Sprengel's deformity, is disproved by the following few examples: two brothers were described recently [12], each suffering from dysostosis multiplex (Pfaundler-Hurler) and bilateral Sprengel's deformity. In a family reported by Perls, the father and two

sons suffered from unilateral undescended scapulae, while in three generations of another family [31] seven members out of twenty had undescended scapulae, three of them bilateral. It is clear from these three examples that Sprengel's deformity, in at least some cases, is a *hereditary condition*.

In contrast to the mechanistic views, the bleb theory explains all peculiarities of the undescended scapula; furthermore, it brings it into closer relation with other syndromes to be mentioned later. The theory has been treated in more detail in the author's former paper [12]. Only a short outline will be given here: Weed described the area membranacea at the roof of the fourth ventricle through which cerebrospinal fluid escapes to form the subarachnoid space. If for some pathological reason—such as the excessive production of cerebrospinal fluid, or its deficient reabsorption—or, perhaps in consequence of a primary dysunion in the mid-line, the area membranacea remains unduly patent, cerebrospinal fluid escapes into the subcutis of the adjacent neck region. The subcutaneous blebs so formed spread on the body surface, and on their path exert a deleterious influence by pressure, and provoke an inflammatory reaction. They are driven by physical forces toward areas of least resistance, and are arrested and retained by preformed cavities and pockets, like the orbits or limb buds. It has been shown experimentally by Bagg and Little, and by Bonnevie that these blebs are the direct cause of manifold deformities in animals,—such as club-foot, claw-hand, and polydactylism. These deformities were obtained in the progeny of mice whose ovaries were submitted to roentgen radiation. Although the deformed second and following generations of mice had not themselves been irradiated, they produced progeny affected, in a high proportion of cases, by the same malformations. The acquired anomalies thus proved to be inheritable, and pathological descendants could be bred through indefinite generations. Blebs, such as these described in Bagg's strain of mice, were observed also in human embryos by Bonnevie, and were associated with anomalies of the fingers and toes. Instructive also are the foetuses of Ingalls showing subepidermal bleb formations over the region of the fourth ventricle, very similar to those seen in mice. Keith attributes these blebs to a defective placental circulation because the chorionic villi were found to be swollen and irregular, and smaller cystic forms were quite plentiful.

It is of great significance that in one syndrome classed among the "bleb diseases"—the "cranio-carpo-tarsal" dystrophy of Freeman and Sheldon—the characteristic bleb, actually found in the neck region, was described as a "jelly-blood" lump; this disappeared three to four days after birth. The blebs remained as constant features of the child's face, and, being situated across the lower part and on each side of the upper part of the forehead, were described as "soft subcutaneous swellings which were shiny in reflected light and moved with the facial muscles".

One should keep in mind that the bleb mechanism is very polyvalent, and that in the experimental animal, as well as in man, blebs may be

responsible for a great variety of deformities. The damage done by the blebs depends on innumerable factors. For instance, the amount of cerebrospinal fluid produced and reabsorbed will determine the *vis a tergo*, and consequently the size, the tension, and the distribution of the blebs. Bagg found that there was a causal connection between the degree of pathological local disturbance in the embryo due to the bleb, and the resulting final deformity. It is to be expected also that, the earlier in development the bleb reaches the periphery, the more extensive will be the damage done.

The experiments of Bonnevie made it clear why and how the same gene, which is responsible for the tendency of abnormal bleb formation, leads also to different anomalous malformations. While the hereditary abnormality as such—the tendency to abnormal bleb formation—is caused by one main recessive gene, other genes modify its manifestations. Each of the modifying genes is responsible for specific features of the embryonic surface. That is why the characteristic distribution of deformities in the American mouse tribe of Bagg underwent important changes after outcrossing with two other races. The following example illustrates this statement: In one mouse tribe the concavity of the shoulder region is greater than in others, and this factor determines the localization of the bleb in this region. The bleb in the shoulder region, on the other hand, extends easily toward the forelegs. These facts account for the prevalence of forefoot deformities in this special mouse tribe.

Let us consider now how the undescended scapula can be explained by the bleb theory. It has been shown that the main avenue of the cerebrospinal fluid leads from the region of the fourth ventricle to the neck, and from here, either via the shoulder region to the anterior surface of the embryo, or, keeping on the posterior aspect, extends toward the back and the lower limb buds. It is evident that the bleb on its way downward has ample opportunity to exert its deleterious effect on the bones—namely, the scapula, the vertebrae, and the ribs—and the surrounding tissues. It has been shown that the ribs and vertebrae are affected in 16 per cent. of the cases of undescended scapula. It is also to be expected that superficial muscles like the rhomboideus and trapezius will suffer by the same factor. It is not known what part these muscles play in bringing down the scapula to its final place, but it is certain that such a function would be grossly inhibited in an area infiltrated with escaped cerebrospinal fluid. Neither will muscles which suffer in their normal development fulfill their later function. In this respect, the complete or partial defect of the muscles, their fibrous appearance, and the interruption of the normal differentiation of muscle fibers at the myoblastic stage, as manifested in Middleton's histological findings, are most significant. They represent the end results of muscles which have undergone degeneration and necrosis at an early embryonic stage, and account for secondary contractions.

One of the most important criteria of the correctness of a theory of a

developmental mechanism is the synchronization of causative factors. It is, therefore, of importance that the bleb formation in the neck region occurs in the fifth to sixth embryonic weeks, and that at this period the shoulder blade is still at the level of the fourth cervical to the first thoracic vertebra. This is also the time when the upper limb bud appears. The distance of the limb bud from the neck region, during the fifth to sixth embryonic weeks is only a few millimeters, so the combination of anomalies of the scapula and of the upper extremity is understandable. This frequent combination cannot be explained, even by the protagonists of the exogenous theory, by action of uterine or amniotic pressure. How could a radius defect, a shortening of the femur and humerus, defective ribs and vertebrae, a bifid ear, a cleft palate, a hypoplasia of the mamma, a congenital inguinal hernia, and many other malformations be explained by uterine pressure? Most of them are, on the other hand, similar to the deformities which were observed in the mouse strain of Bagg, or which the author described as signs of the bleb diseases.

No attempt will be made to explain these associated malformations separately. It is obvious that a bleb which may appear at any part of the body surface will act locally either by destroying the tissue or by modifying its normal course of development. The route of the bleb will be responsible for the associations of the different deformities; hence the upper extremity is more frequently affected than the lower one.

A strong argument in favor of the undescended scapula being one of the bleb diseases, is the fact that it constitutes one of the signs of the dysostosis multiplex which belongs to the bleb-disease group. In a high proportion of these cases, an undescended scapula was recorded, and explained by the bleb mechanism.

There are two cases of Sprengel's deformity which deserve special attention because they support the above view. One is that of Critchley, in which the undescended scapula was associated with paraplegia due to syringomyelia, an asymmetry of the face, a difference between the two upper and two lower extremities, an inequality of the palpebral fissure, and a heterochromia iridis. The other is that of du Toit in which the elevation of the scapula was combined with a defect of the cervical spine and a typical syringomyelia. It is not the author's object to discuss here the etiology of the latter disease; let it suffice to say that, according to competent authors [16], at least some of the cases are due to an anomaly of development (dysraphia) of the central nervous system. Thus it is reasonable to assume that in these two cases the syringomyelia is a pathological condition of the same order as the patency of the area membranacea [41] which is suggested as the primary cause of the undescended scapula.

It may rightly be asked, "Is there any direct sign of a bleb in the neck region of patients affected by undescended scapula, as postulated by the author's theory"? This question can be answered in the affirmative. There are two cases which can be produced as proof: One is Horwitz' Case II which he described as follows: "The curvature and

the high shoulder were noticed at the age of one, a 'lump' on the back having been observed some time previously". This case presented also a "slight facial asymmetry; high arched palate; slight strabismus; a half-inch shortening of the humerus; absence and irregularity of ribs; and wedge-shaped vertebrae".

If the meaning and the above description of the "lump" is rather vague, it is more explicit in the case of Bizarro: In a boy of fourteen, a short neck was noticed soon after birth. "It had something like a round soft tumour at the nape, but in time this fatty formation disappeared." The child weighed four kilograms at birth, so that forceps had to be applied. Other anomalies noticed were a high palate, dull hearing, short and narrow auditory canals, and a deformed chest. The face was mongoloid and expressionless, the nape hairline was lowered, the scapula was elevated; *the neck was webbed;* and the sella turcica was slightly enlarged.

If it is considered that in two other syndromes belonging to the bleb-disease group, a very similar transitory lump was recorded in the same region, then the analogy between the latter and Bizarro's "fatty formation" cannot be overlooked. In a case of dysostosis multiplex [17] this finding was described as follows: "The skin over the occiput was thickened and felt spongy." The lump described as "jelly blood" in a case of cranio-carpo-tarsal dystrophy [15] has already been mentioned.

The two cases of Horwitz and Bizarro are the only ones which so far have come to the author's attention as giving unmistakable direct evidence of a "bleb" in the neck region, though his search for it has been incomplete. Bizarro, however, mentions that patients with Sprengel's deformity frequently display a "webbed, wing-like neck" which is only a subvariety of the cutis laxa, both being the end result of an arrested bleb [13]. Webbed-neck is also a constant feature of another member of the group of bleb diseases described by Turner.

If it is considered in addition, that the cases of undescended scapula are brought to the surgeon usually several months or years after birth, it will be understood that "lumps" in the neck of transitory character are frequently overlooked, and, if observed, they are very likely to be mistaken for a cephalhematoma. Another reason why observation of early blebs is so rare is that embryos with very gross deformities do not frequently survive, but lead to early abortion. A closer study of aborted foetuses would contribute considerably to our knowledge.

Two further noteworthy findings were recorded by Kirmisson, and Sainton. They described a congenital cutaneous scar above the deformed scapula. It is known from Bagg's experiments that the cerebrospinal-fluid blebs may result in necrosis and scar formation in the areas affected. In view of other evidence, the scars of Kirmisson and of Sainton would appear to be of similar origin.

Two clinical entities are closely related to Sprengel's deformity, from a clinical as well as from an etiological standpoint: One is symbrachydactylia, and the other is the Klippel-Feil syndrome.

The Klippel-Feil syndrome is characterized by shortness of the neck caused by abnormalities,—such as, fusion and reduction in the number of the vertebrae, with secondary scoliosis or kyphosis and restricted head-neck movements; low implantation of the hairline; frequently webbed neck caused by a winglike stretching of the trapezius; an elevated scapula; torticollis of osseous or muscular origin; disproportion between the length of the extremities and the trunk; and descent of the nipples. It is often associated with spina bifida, cleft-palate, facial asymmetry, abnormal dentition, deformed forearm, club-foot, club-hand, and muscle and bone defects in the thoracic, lumbar, and sacral regions. Neurological complications are very frequent and consist, among others, of mental weakness, deaf-mutism, spastic paraplegia, syringomyelia, and pseudomyopathy. A familial tendency is noted. From the pathological standpoint, it is noteworthy that in many cases a large triangular opening is present in the occiput and the cervical spine, sometimes extending even to the thoracic part, and frequently is associated with a caudal displacement of the brain and spinal cord (Arnold-Chiari deformity).

From this description, it is evident that the Klippel-Feil syndrome and Sprengel's deformity have many signs in common. In both, the descent of the shoulder girdle is incomplete; in both, there may be an absence or anomalies of the vertebrae, and anomalies of the ribs; both often display a webbed winglike neck; both are often associated with other anomalies of a very similar character; both conditions are hereditary.

As to its etiology, nothing definite is known. Mau expresses the view that the primary changes are in the central nervous system, and the skeletal deformities are of a secondary nature. Aschner and Engelmann consider the abnormalities of both as coordinated conditions from the same primary cause, but all authors, with perhaps the exception of Klippel and Feil, agree that the Klippel-Feil syndrome is not due to exogenous disturbances.

Two cases of Feller and Sternberg deserve special attention because they shed some light on the etiology. One is their Case 1, in which the *skin of the chin bridges the angle of the neck*, passing on directly to the sternum and from the occiput to the back; the normal contour of the neck is missing entirely, and the skull is slightly hydrocephalic. There are extensive changes of the vertebrae and ribs typical of the syndrome.

In their Case 2, the short neck was associated with a hydrocephalus and with *folded slack skin over the neck region.* A cephalomeningocele protruded through the posterior pharynx. *The roof of the fourth ventricle*, which was dislocated below the level of the third thoracic vertebra, *consisted only of the thin tela choroidea.*

The morphological similarity between the two syndromes—the Klippel-Feil syndrome and Sprengel's deformity—has been pointed out already. The differences between the two are not of a qualitative but are rather of a quantitative nature. The two cases of Feller and

Sternberg are evidence that the analogy between the two syndromes extends also to etiology. The hydrocephalus, the cutis laxa in the neck region, and especially the histological finding of the brain—the *thinned-out roof of the fourth ventricle consisting of only one fine choroid layer*—are just the findings postulated by the bleb theory.

The etiological relationship of the other syndrome, the *symbrachydactylia*, with Sprengel's deformity is not so manifest as with that of the Klippel-Feil syndrome. Still it appears justified, as will be seen, to classify it with the same group. The symbrachydactylia is characterized by shortness and other anomalies of the fingers, combined with syndactylism. It affects principally the upper, and hardly ever the lower, extremity. The nails are often abnormal; and the radius is sometimes missing. In twenty cases out of thirty, a hypoplasia of the hand, with or without shortening of the upper extremity, was present.[34] In 50 per cent. of the cases, defects of the thorax wall and the pectoral muscle were recorded. The association with undescended scapula, defects of ribs and clavicle, and anomalies of the mamma are very frequent. It is of great interest that the skin between the arm and thorax is often webbed,—a feature so frequently seen in bleb diseases.

A comparison of this clinical picture with the undescended scapula and the Klippel-Feil syndrome shows that, while in the latter two the deformities of the shoulder girdle govern the picture and are often associated with deformities of the upper extremity, in the symbrachydactylia the reverse is the case; the deformed extremity is in the foreground, and the abnormalities of the shoulder girdle, especially the undescended scapula and congenital defect of the pectoral muscle, are concomitant, though frequent signs. In short, there is a difference in the proportional distribution of the same signs between the two, but no difference in principle. From the standpoint of etiology, the frequent webbed skin is an indication that in some period of development the skin was unduly overstretched by cerebrospinal-fluid blebs. The preferential affection of the upper extremity is characteristic for all bleb diseases, and is due partly to the earlier development of the upper limb bud, compared with the lower, and partly to the proximity of the upper limb bud to the skull, the source of the blebs. Symbrachydactylia and similar deformities are also very common in the mice of Bagg and Little. It is therefore not too unreasonable to classify symbrachydactylia among the bleb diseases.

In the foregoing, three syndromes have been discussed which at first appear to be distinct clinical entities, but on closer examination have very much in common. They all concern the shoulder girdle or its appendage,—the upper extremity. They are all different manifestations of the same etiological factor. In discussing the three clinical pictures separately, an attempt has been made to collect signs which support the view that the deformities were caused by the peripheral damage from cerebrospinal blebs. Such signs, in the shape of spongy large lumps in the neck

region, or of cutis laxa, were found in all three. In one case of Klippel-Feil syndrome, in which a postmortem and a histological examination of the brain were possible, a hydrocephalus and a reduction of the roof of the fourth ventricle to the choroid membrane, as postulated by the bleb theory, were found. For obvious reasons it is hardly possible to offer more evidence in favor of the bleb theory than traces of blebs or their sequelae,—the damage done by the blebs. The question has been discussed more in detail in the author's first paper.

Accepting the bleb theory for these three syndromes, the differences in the bleb manifestations can be explained by their different localization and retention, by their different size and consequent pressure, and finally by the time of their reaching the periphery. If the bleb, descending from the neck, takes a more anterior route, with a final arrest and maximal pressure at the end of the limb buds, a symbrachydactylia will be the result, with possible damage to structures lying between the point of departure and the end station. If, on the other hand, the bleb remains on the posterior embryonic surface, two possibilities may follow: Either the bleb action will be more distal, and by that time more superficial, in which case a Sprengel's deformity will develop, with or without complications; or the bleb will be retained in the neck region, nearer its origin, with less diffuse, and therefore deeper action, in which case a Klippel-Feil syndrome will be the manifestation. The transitional stages between the three syndromes and other additional deformities offer no difficulties to understanding.

The reason for singling out these three syndromes from a larger group, is their localization around the shoulder girdle. Otherwise they are members of the larger family of bleb diseases, similar to those mentioned by Ullrich, and Keith, and discussed in the author's first paper.

There is one question of fundamental importance which should be mentioned briefly. It concerns all bleb diseases, and therefore also these three syndromes: Advances made during recent years in developmental mechanics, especially the experiments of Spemann and his school [26,28], have shown that the presumptive medullary material alone is not capable of any self-differentiation. The notochord and the somites (mesoderm) both have a great influence on the normal development of the overlying neural plate. It seems from experimental evidence, that the notochord has an organizing, arranging influence on the medullary material, which can only come into action when the notochord is situated directly below the medullary plate. The absence of the notochord generally leads to a median fusion of the somites, which are normally separated. Lehmann assumes that the cells of the somites, during the closing of the neural tube, exercise some sort of "polarizing" influence on the neural epithelium.

This condition is illustrated in Figure 1. As explained by Spemann, the normally developing neural tube is divided into two lateral masses, connected both dorsally and ventrally by a thin plate of cells, which together enclose a narrow cavity. The long axis of this cavity, as seen in

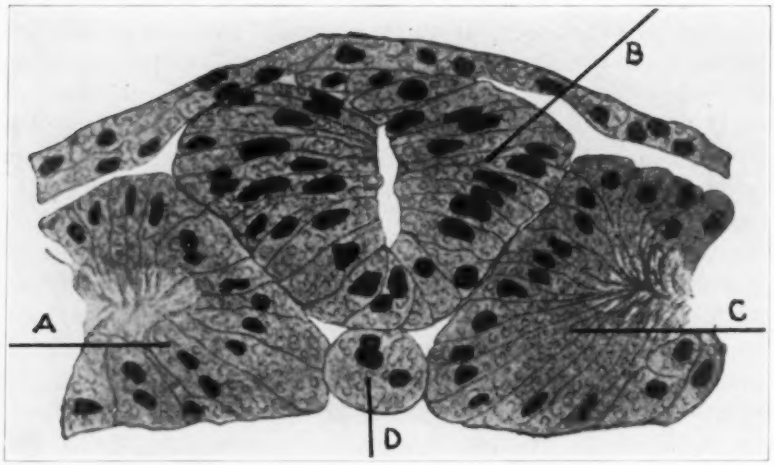

FIG. 1

Cross section through a normal young embryo of Triton. The walls of the neural tube consist of a one-cell layer. Under it lies the notochord, separating the two somites. (*Reproduced from Die Bedeutung der Unterlagerung für die Entwicklung der Medullarplatte von Triton, von Fritz Erich Lehmann, in Wilhelm Roux' Archiv für Entwicklungsmechanik der Organismen, CXIII, S. 132, Abb. 8, 1928.*)

A: Somite. *B:* Neural tube. *C:* Somite. *D:* Notochord.

cross section, coincides with the dorsoventral axis of the body. If, however, under pathological conditions, the notochord is missing (Fig. 2), then the two somites fuse in the mid-line, and the neural tube shows invariably an entirely different arrangement. The latter then consists of a thick undivided base (basal mass) with a thin roof. The plane of the long axis of the cavity coincides with the frontal plane of the body.

These findings are of great importance for the understanding of the bleb diseases, because the latter are believed to be the result of a defective closure of the neural tube in the region of the fourth ventricle. It is possible that this dysunion is also due to a disturbance caused by the somites or the notochord, analogous to the experimental findings of Lehmann, Mangold, and others.

This view is supported by the fact that, in the mice of Bagg and Little, an atrophy of the kidneys was observed in addition to the bleb deformities. Ullrich saw also anomalies of the urogenital tract in human cases, which he considered to belong to the bleb-disease group. As the kidneys are formed by the somites—the same mother tissue which, as has been seen, influences the normal development of the neural plate and its derivates—it is likely that both neural tube and kidneys suffer from the same primary lesion,—a disturbance of the somites. It is possible, on the other hand, that the neural tube and the somites are simultaneously affected, and the anomalies of their corresponding derivates are coordinated features. Only histological studies of malformed embryos can decide between these two alternatives.

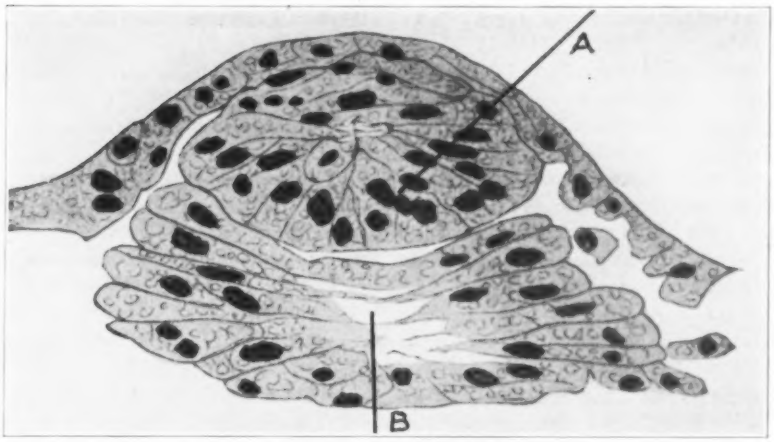

FIG. 2

Cross section of an embryo of Triton of the same age as that in Figure 1. The notochord and parts of the somites are lacking; the somites are fused in the mid-line; the lateral walls of the neural tube are not differentiated, but form a solid "basal mass". (*Reproduced from Die Bedeutung der Unterlagerung für die Entwicklung der Medullarplatte von Triton, von Fritz Erich Lehmann, in Wilhelm Roux' Archiv für Entwicklungsmechanik der Organismen, CXIII, S. 147, Abb. 20, 1928.*)

A: Basal mass. *B:* Fused somites.

If one accepts the kidney anomalies as being caused by a primary lesion of the somites (mesoderm), then one cannot deny that other mesodermal derivates—such as bones and muscles—may be injured by the same factor. It is clear from these facts that it is possible that two mechanisms are responsible for the deformities in the bleb diseases. By one, the deformities develop because the mother substance, the mesoderm, is defective. By the other, the potentialities of the organs are normal, but the tissues are disturbed in the normal course of development by the local action of the blebs, which themselves may or may not be the result of a mesodermal (somite) lesion.

By classing the three syndromes—Sprengel's deformity, Klippel-Feil syndrome, and symbrachydactylia—among the bleb diseases, a further group of deformities has been brought nearer to understanding. On the other hand, the evidence given in favor of this view is at the same time a further support of the bleb theory in general. It is believed that this theory has a greater scope in the pathology of malformations than is generally known.

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STABILIZATION OF THE ARTICULATION OF THE GREATER MULTANGULAR AND THE FIRST METACARPAL

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Dislocation of the thumb at the articulation of the first metacarpal and greater multangular is a rather unusual occurrence. When chronic and painful, it presents a difficult orthopaedic problem not amenable to conservative treatment. Stabilization by ligamentous reconstruction, osteotomy, and fusion of the joint have been described, but have the disadvantage of either too nearly complete or incomplete stabilization,—that is, fusion will eliminate all motion of the joint, while osteotomy and ligamentous reconstruction frequently results in incomplete fixation with some residual pain.

Since intra-articular tenodesis has become generally accepted in the Nicola procedure for recurrent dislocation of the shoulder, it occurred to the writer that this principle might be applied to stabilization of the

FIG. 1-A

Roentgenogram showing dislocation at the articulation of the first metacarpal and the greater multangular.

FIG. 1-C

FIG. 1-B

Showing range of motion following stabilization.

articulation of the first metacarpal and greater multangular, incorporating additional strength by capsular reinforcement.

TECHNIQUE

Through a curved longitudinal incision, one and one-half inches long, paralleling the extensor pollicis longus at the distal end of the anatomical snuff box, the articulation of the first metacarpal and greater multangular is exposed. From a point about one-half inch distal to the joint, a hole is

FIG. 2-A

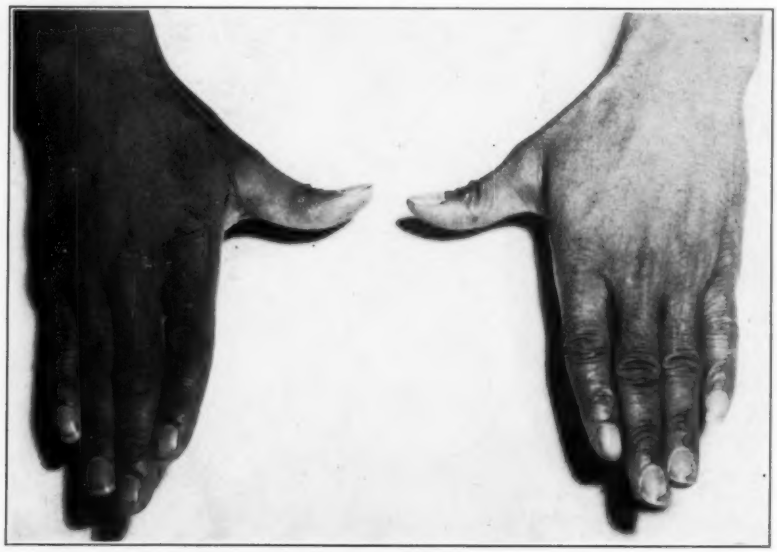

FIG. 2-B

FIG. 2-C

Figs. 2-A, 2-B, and 2-C show the range of motion following stabilization.

drilled obliquely downward through the metacarpal to the center of the joint to coincide with a similar drill hole originating from the dorsolateral aspect of the greater multangular. A piece of palmaris longus tendon is then threaded through the drill holes, and, while the thumb is held in moderate opposition, is sutured back upon itself to form a loop. The joint will then be found to be stable, although freely movable. The remaining length of tendon is then plicated across the back of the joint to form a new posterior capsular ligament. The skin is closed in the usual manner, and a cast is applied with the thumb in the neutral position. After three weeks, the cast is removed, and active motion and physiotherapy are instituted.

CASE REPORT

On May 15, 1942, the patient, a colored male cook, twenty-two years old, injured his thumb during fisticuffs. Pain and swelling at the base of the thumb were immediate. The patient continued his work as a cook, however, in spite of pain which was aggravated by frequent spontaneous dislocations of the base of the thumb, as well as by gripping, pinching, and holding objects in his hand while the forearm was in supination. He treated himself by means of hot-water soaks. Examination on June 27, 1942, revealed marked weakness of the grip. Abduction of the thumb was only 75 per cent. of normal as compared with the opposite hand, with a corresponding decrease in the web angle between the thumb and index finger. On opposition and pinching the thumb against the index finger, the base of the first metacarpal dislocated spontaneously, and was associated with mild crepitus. The joint could easily be dislocated and reduced passively. Tenderness was present over the dorsal and medial aspects of the joint.

The patient was operated upon July 3, 1942, according to the previously described technique. The cast was removed in three weeks, and mobilization of the hand was begun by means of active motion and whirlpool baths. The patient was discharged to

full duty on August 15, 1942. On last examination, eight months after operation, the patient had a full range of normal, painless motion in the joint, with nearly normal power in the pinch and grip as compared with the opposite hand. Roentgenograms at this time revealed the joint to be stable.

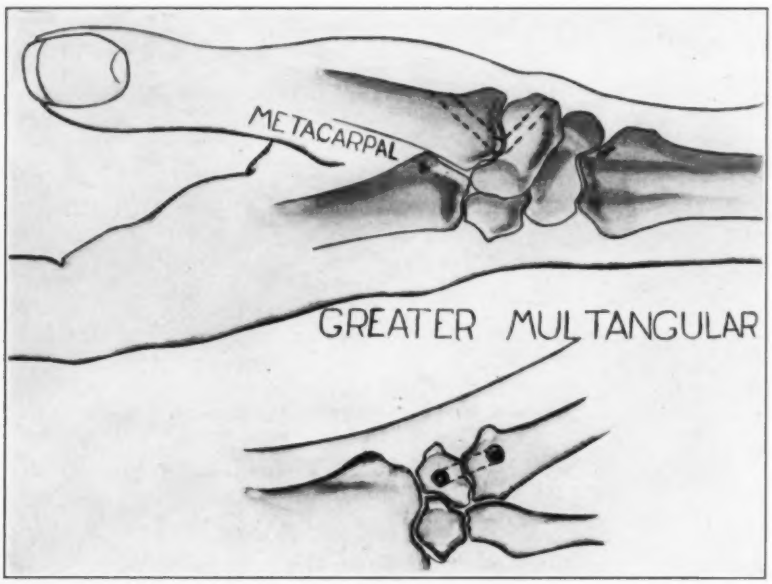

FIG. 3

Diagrammatic representation of placement of drill holes for the reception of the palmaris longus tendon.

The author believes that this procedure allows the maximum stabilization obtainable, while still retaining a full range of joint motion. It is felt that this method would also be of value in selected cases of old fracture-dislocation of the first metacarpal base of the Bennett type.

PIN DISTRACTION AS THE CAUSE OF NON-UNION *

BY ARTHUR G. DAVIS, M.D., ERIE, PENNSYLVANIA

The purpose of this paper is to show the unique capacity for damage possessed by pin-distraction apparatus, and to present an explanation of the cause of non-unions following the use of such apparatus. Within the short period of nine months, no less than six flail non-unions of the lower tibia were referred to the Orthopaedic Service of our local hospital. These cases were strikingly similar in appearance. This unusual similarity immediately suggested the existence of a special factor at work. From the history and serial roentgenograms it seemed that something more was at work to produce non-unions than the usual causes. All six cases had been subjected to pin distraction. Complete serial roentgenograms from the date of accident fortunately were available in all cases. It was immediately apparent from the films that overdistraction was attained and maintained throughout the critical callus-forming period.

A sliding bone-graft operation succeeded in each case in securing union without complications, and in average time. It is, therefore, clear that there was no question of lack of inherent bone-forming ability on the part of any of the subjects. The average time between the bone-grafting operation and unsupported weight-bearing was four and one-half months,—the longest six months, and the shortest three months. Each patient returned to his former occupation.

It is not intended here to enter the highly controversial subject of callus formation. Since, however, the present state of our knowledge leaves the process of bone repair still largely in the realm of inexplicable phenomena, one is restricted in the analysis of this unusual group of cases to the broadest generalities. Clinical and roentgenographic data seem more dependable than laboratory evidence. Assuming, then, only the usually accepted generalities governing callus formation—that is, the existence of humoral, cellular, and mechanical factors—the fact that union occurred promptly following ordinary bone graft eliminates at once the humoral and cellular components, and focuses the fault on the mechanical factor alone. The question then resolves itself into an analysis of the unique mechanical factor, introduced by a method which depends upon one or more pins transfixing each main fragment with both unit assemblies connected by a distracting device. It is obvious immediately that a high degree of mechanical efficiency is introduced by such gear or screw mechanism pushing two skeletally fixed units in opposite directions. With ordinary manual manipulation the potential for disruption or overtraction is much less if not entirely absent. Skeletal traction on the distal

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 19, 1943.

fragment alone is more easily controllable. Open reduction with plating aims at hairline apposition of multiple bone-forming layers. In the latter case, there being no dead space between bone ends, the periosteum is less essential. The ever-present temptation with pin distraction is to overpull to attain apposition and alignment. It is quite impossible to feel the difference in an adjustment d pending upon a gear as between *just enough* and *too much* force. The tensile strength of the periosteum is such that ordinary traction with hand or weights will not disrupt this essential membrane completely. On the other hand, pin distraction which is in common use today, particularly overdistraction, has this potential, and will cause complete horizontal disruption of the periosteum. Where there is overriding at the time of reduction, the distracting force must overpull, because angular manipulation is not used to engage the fragments. The difference is the difference between complete horizontal severance of the periosteum and the preservation of continuity of part of the periosteum.

Six cases of non-union are reported (Cases 1, 2, 3, 4, 5, and 6). In each case either the lateral or the anteroposterior projection, whichever showed the better, was used throughout the case, but in no case are both projections shown in the same case. Case 4 is shown in greater detail

FIG. 1-A FIG. 1-B FIG. 1-C FIG. 1-D FIG. 1-E

Case 1. E. N. Non-union.

Fig. 1-A: November 28, 1940, date of accident.

Fig. 1-B: December 4, 1940, pin traction was introduced.

Fig. 1-C: March 10, 1941, status thirteen weeks later.

Fig. 1-D: April 14, 1941, non-union was demonstrated and operation was performed on April 25, 1941.

Fig. 1-E: October 21, 1941, six months after bone graft.

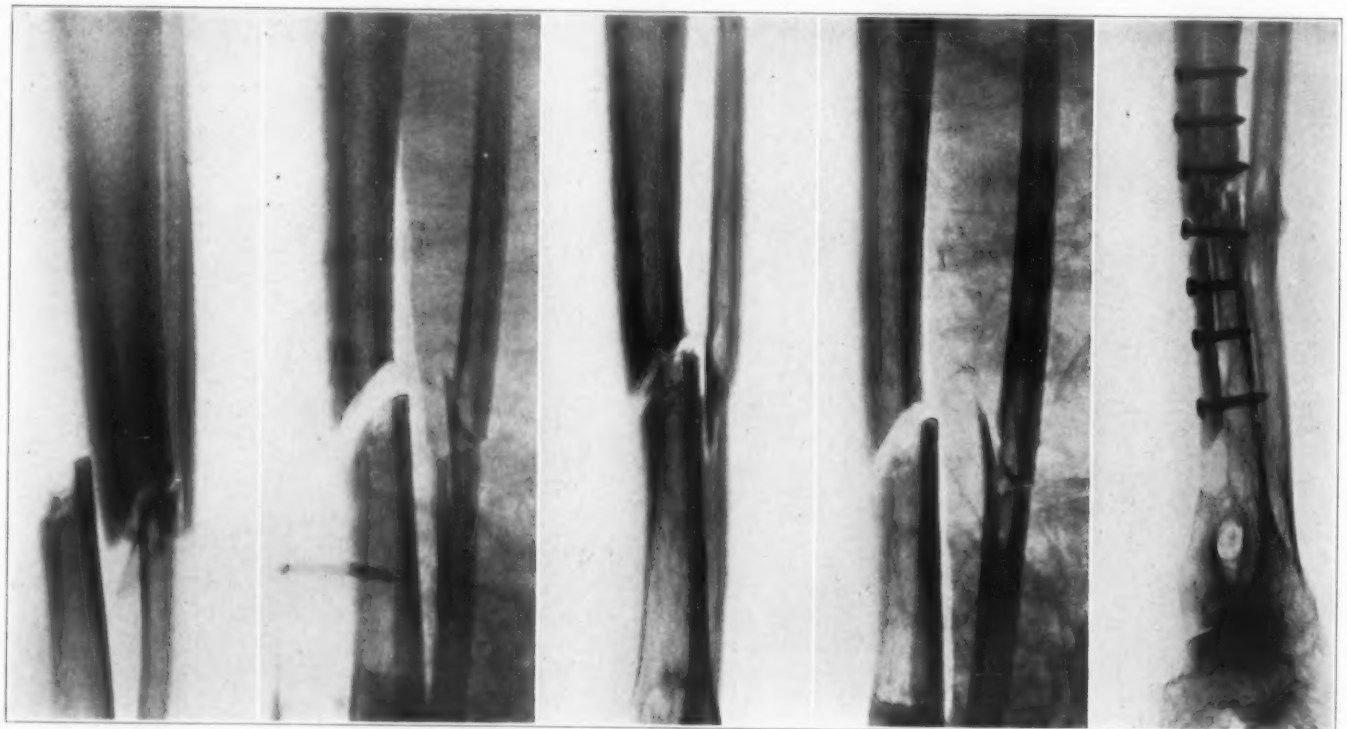

FIG. 2-A FIG. 2-B FIG. 2-C FIG. 2-D FIG. 2-E

Case 2. W. B. Non-union.

Fig. 2-A: August 13, 1940, date of accident. Plaster was applied.
Fig. 2-B: August 24, 1940, pin traction is in place.
Fig. 2-C: August 31, 1940, after adjustment of overtraction.
Fig. 2-D: April 11, 1941, non-union was demonstrated and operation was performed on May 2, 1941.
Fig. 2-E: August 26, 1941, patient is weight-bearing without support.

because of an intermediate plating operation following non-union from pin distraction. Also shown are two cases of delayed union in which the fracture had been reduced by the same pin-distraction method (Cases 7 and 8); and one, treated by the author from the beginning, in which internal fixation was used, distraction having been inadvertently introduced with a Lane skid (Case 9). Bony union was eventually obtained after many months of protection. Case 10, of a different type, was also the author's from the beginning, and exhibits the injudicious use of skeletal traction combined with a large extruded fragment of bone which in the author's opinion is simply another example of what occurs when the ingress between the two main fragments of interposed fibrous tissue is allowed. Figure 11 attempts to describe graphically the mechanism in play in the usual circumstances as contrasted to that occurring when overdistraction takes place.

DISCUSSION

Innumerable warnings have been issued in the past concerning the danger of overtraction. Prolonged clinical experience has taught the majority of men handling fractures that separation of the two main bone fragments, even a very slight amount, induces delay in the bone-healing process. Notable among these warnings is that of Roger Anderson in his original contribution in 1932. Quite recently Bradford and Wilson report outstanding results using improved units such as the latest type Roger

FIG. 3-A FIG. 3-B FIG. 3-C FIG. 3-D

Case 3. B. S. Non-union.

Fig. 3-A: November 17, 1941, date of fracture.

Fig. 3-B: January 6, 1942, status one month after introduction of the pins.

FIG. 3-C: January 12, 1942, no promise of union; operation was performed January 22, 1942.

Fig. 3-D: May 19, 1942, four months after operation, the patient is ambulatory without support.

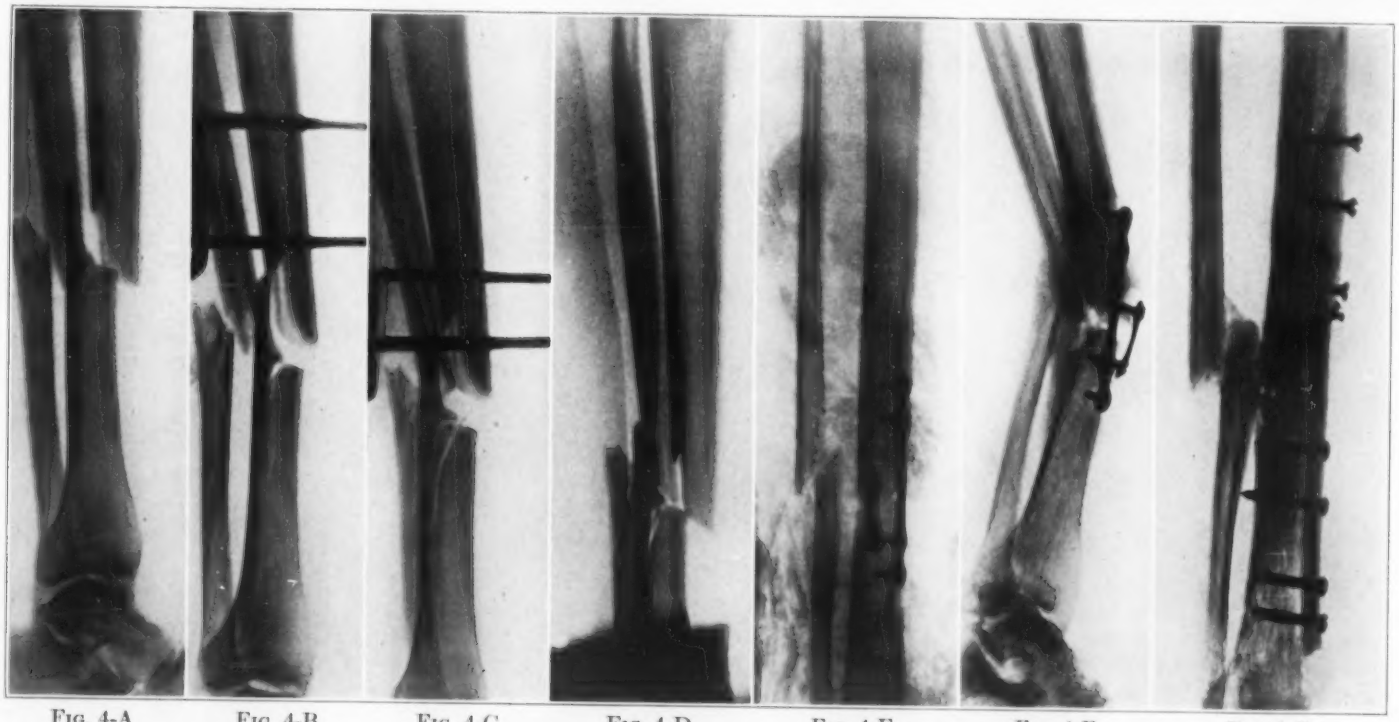

FIG. 4-A FIG. 4-B FIG. 4-C FIG. 4-D FIG. 4-E FIG. 4-F FIG. 4-G

Case 4. A. B. Non-union.

Fig. 4-A: August 27, 1940, date of fracture. Patient was in Thomas splint.
Fig. 4-B: September 3, 1940, pin traction had been applied to heel.
Fig. 4-C: September 12, 1940, the separation had increased.
Fig. 4-D: September 25, 1940, traction was abandoned.
Fig. 4-E: October 5, 1940, a plating operation was performed.
Fig. 4-F: April 12, 1941, the patient was admitted to Hamot Hospital with a non-union. Bone-graft operation was performed April 23, 1941.
Fig. 4-G: August 29, 1941, patient is ambulatory without support four months after operation.

Anderson, and Haynes and Waknitz apparatus. These authors stress at length the danger of overtraction. The latest contributions to the subject of pin distraction point to the necessity for the elimination of shear strain and the induction of compression strain. They claim that fixation at the point of fracture is more complete and that the callus-forming process is hastened because of early weight-bearing. Such apparatus would seem to be particularly applicable for the fixation of fractures accompanied by an open wound. The temptation to use such apparatus to meet the exigencies created by mobile warfare is at this moment very great. The need to facilitate transport is obvious, and any method which promises to do this and still not interfere with union must obviously be seriously considered. However, because of the ever-present danger accompanying all pin-distraction methods, it would appear that regardless of the efficiency of the apparatus, the prerequisites of the operator will play the dominant rôle in the fate of the extremity.

FIG. 5-A FIG. 5-B

Case 5. G. C. The fracture occurred in January 1941. Pin traction was used and the patient was kept in plaster six weeks. The pins were then removed and a skin-fitting plaster was applied. On August 22, 1941, the patient was admitted with a non-union, and a bone graft was performed August 25, 1941. Patient was ambulatory without support three months later. The roentgenograms were taken November 19. (Preliminary x-rays have been lost.)

Whether the fragments are impaled upon the fixation units by one or more pins, whether the pins are half pins or transfix both cortices, or whether angulated as in the Stader apparatus, does not affect the capacity for damage. The damage is a danger inherent in the gear, screw, or turnbuckle separating unit used to connect the transfixion units. It may be said that the more unyielding the hold on the fragment and the more mechanically efficient the distraction, the greater is the potential for rending asunder soft parts and periosteum.

Much has been said about the technical requirements and armamentarium of the surgeon who attempts to do internal fixation with bone plates. It would appear that the operator attempting to reduce fractures and manage them by pin traction will require more precision, better judgment, a broader clinical experience, and more thorough grounding in the fundamentals of bone repair.

The accompanying illustrations of non-union and delayed union give cause for grave apprehension regarding the oncoming hordes of fractures which may be reduced in this manner. The fact however that overdistraction has occurred does not necessarily mean that the damage done is irrevocable.

John R. Moore is of the opinion, when roentgenographic evidence is present of appreciable separation resulting from pin distraction, that immediate impaction is imperative, and that the majority of such overdistractions should be openly reduced to be assured of hairline apposition and impaction. This precaution seems entirely merited since it must be assumed that the periosteal tube is severed horizontally, and that one must be doubly certain of the close apposition of all remaining bone-forming layers, so as to attain union.

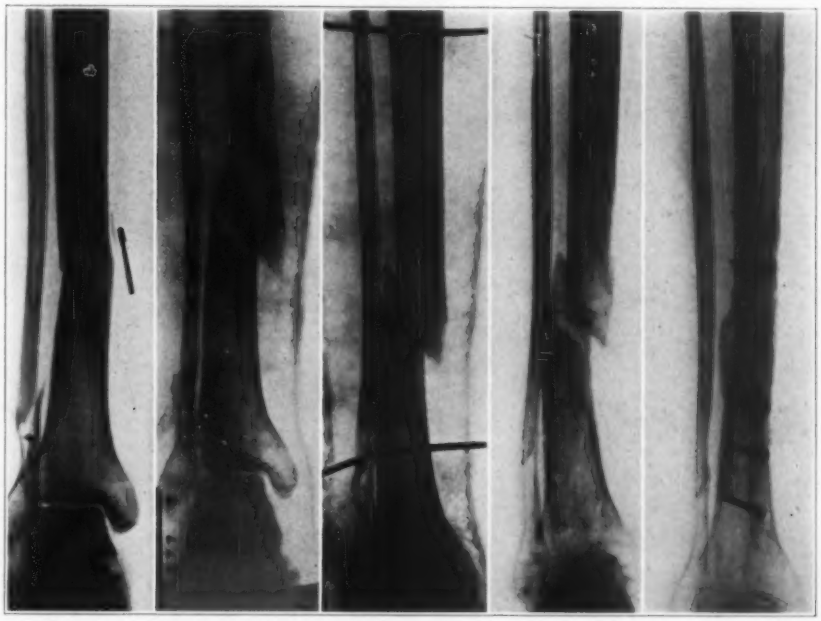

FIG. 6-A FIG. 6-B FIG. 6-C FIG. 6-D FIG. 6-E

Case 6. H. O. Non-union.

Fig. 6-A: November 4, 1940, date of fracture. A skin-fitting plaster was applied.

Fig. 6-B: November 23, 1940, the position is unsatisfactory.

Fig. 6-C: November 29, 1940, pin-traction was applied.

Fig. 6-D: April 22, 1941, non-union was evident. Bone-graft operation was performed May 8, 1941.

Fig. 6-E: October 11, 1941, five months after operation, the patient is ambulatory without support.

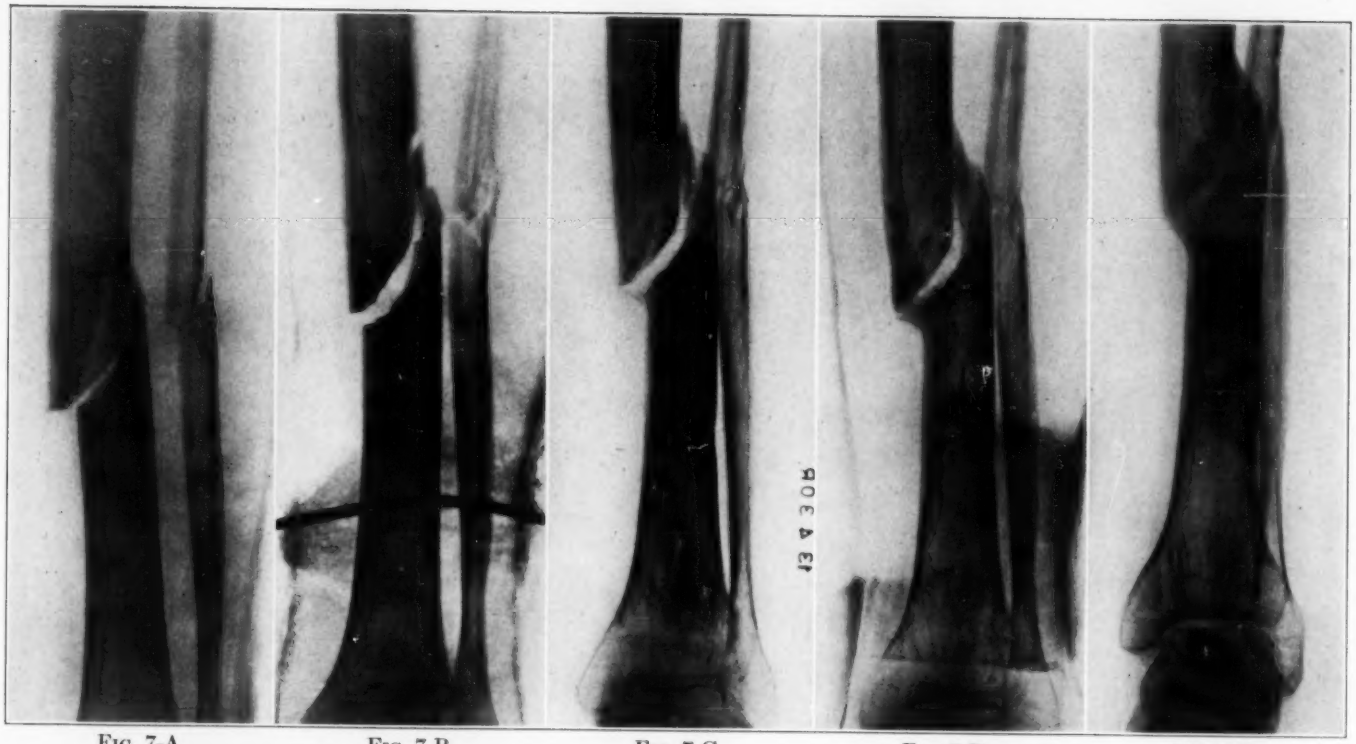

FIG. 7-A FIG. 7-B FIG. 7-C FIG. 7-D FIG. 7-E

Case 7. S. Delayed union.

Fig. 7-A: November 12, 1940, fracture had occurred the previous day.
Fig. 7-B: November 19, 1940, pin distraction was used.
Fig. 7-C: July 1, 1941, threatened non-union.
Fig. 7-D: September 9, 1941, interval appearance.
Fig. 7-E: May 2, 1942, the patient is ambulatory without support eighteen months following the fracture.
Note the persistence of intra-osseous space in Figs. 7-C, 7-D, and 7-E.

For the following reasons it is thought that the special cause at work in the foregoing cases was that of a complete circumferential annular rent of the periosteum. The evidence of the roentgenographic serial story from the date of the fracture to the flail union in each case, together with the evidence offered at the time of operation, brings one inevitably to the conclusion that the difference between these non-unions and those ordinarily encountered as a result of motion at the point of fracture is the status of the periosteum. At the time of operation the following observations were made:

1. There was not a vestige of callus formation over the bone ends of the two main fragments.
2. The material between the bone ends was entirely fibrous in nature.
3. A negligible ring of calcification was found a short distance back from the fractured surfaces.
4. There was no evidence of soft-part interposition in any case.

It is obvious that, with the amount of distraction herewith illustrated, it would be quite impossible to have interposition of soft parts.

Assuming, then, that, besides appreciable separation of osseous substance, complete circumferential rents of an annular type have also occurred, it is self-evident that two different phases are permitted free access to the open space between the bone ends. It is also obvious that two dif-

FIG. 8-A FIG. 8-B FIG. 8-C FIG. 8-D

Case 8. T. S. Delayed union.

Fig. 8-A: November 1, 1940, date of fracture.

Fig. 8-B: November 2, 1940, skin-fitting plaster was applied. There is posterior bowing.

Fig. 8-C: November 12, 1940, pin traction has been applied, and the bowing has been corrected. Note extensive comminution explaining periosteal continuity.

Fig. 8-D: April 2, 1941, patient started weight-bearing. Unrestricted weight-bearing was permitted in July 1941, eight months following fracture.

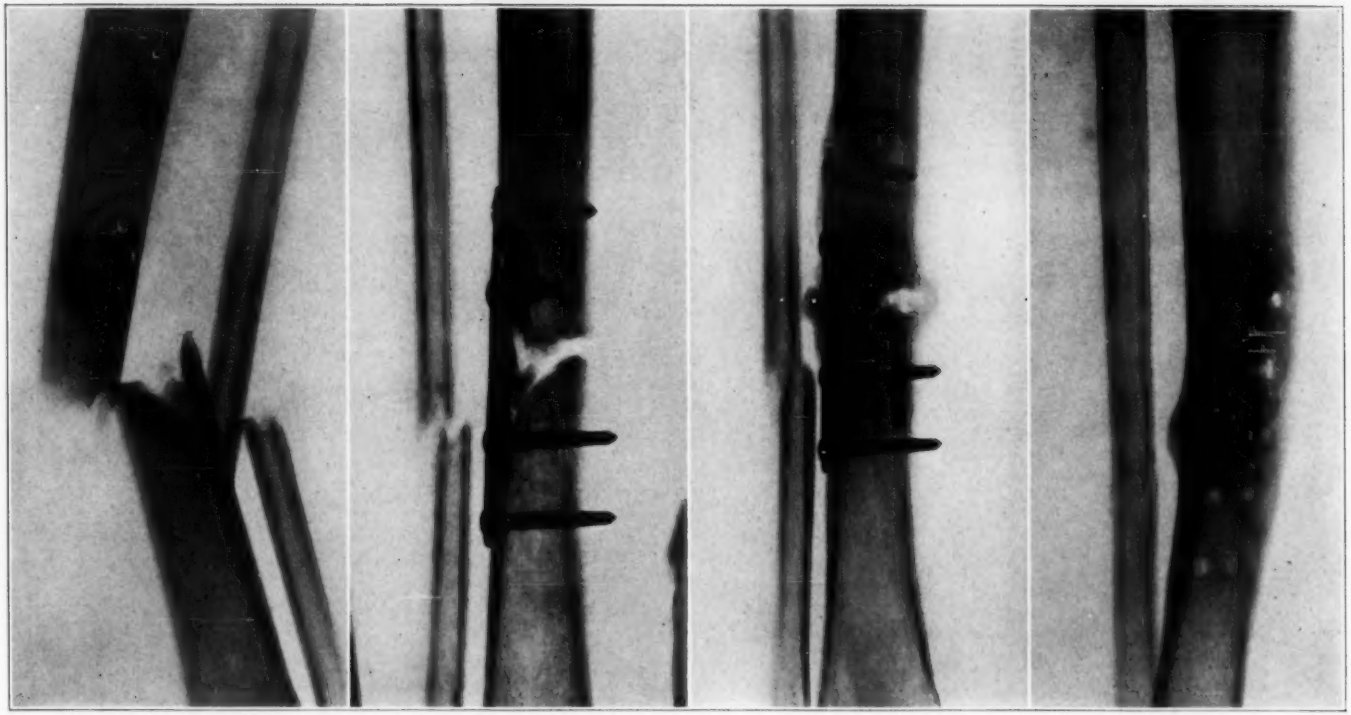

FIG. 9-A FIG. 9-B FIG. 9-C FIG. 9-D

Case 9. G. B. Delayed union.
Fig. 9-A: May 17, 1937, date of fracture.
Fig. 9-B: May 25, 1937, the fracture has been plated. Note the gap.
Fig. 9-C: July 25, 1937, the gap has persisted.
Fig. 9-D: June 25, 1938, one year later the plate has been removed and the patient is weight-bearing without support. Note the migration of callus from the side showing continuity.

ferent healing processes are present at every fracture. The one process, initiated by injury to the soft parts, has as its final goal fibrous tissue, and never undergoes ossification. This most primitive and universal healing process necessarily is in immediate juxtaposition to the fracture site. The other process, initiated by injury to bone, creates bone under certain minimal conditions. It is generally accepted and a matter of daily clinical experience that contact of any one of the bone-forming layers, whether it be periosteum, cortex, cancellous bone, or endosteum, of one main fragment to any one similar or dissimilar osseous layer of the other main fragment, is sufficient for some kind of union, fragile though it may be, to occur.

Beveridge Moore has shown how extremely difficult it is to induce complete circumferential annular rents, of the kind produced by pin distraction, by manual manipulation, even when the bones are stripped of their surrounding musculature. The behavior of the periosteum, that is, its tendency to slide off the cortical layer laterally because of its loose attachment, permits the periosteum to remain intact in its longitudinal axis regardless of large amounts of comminution, angulation, and overriding, so that it is difficult to conceive how circumferential annular rents can be induced in the periosteum except by the pin-distraction method.

Because of the evidence encountered in the open reduction of frac-

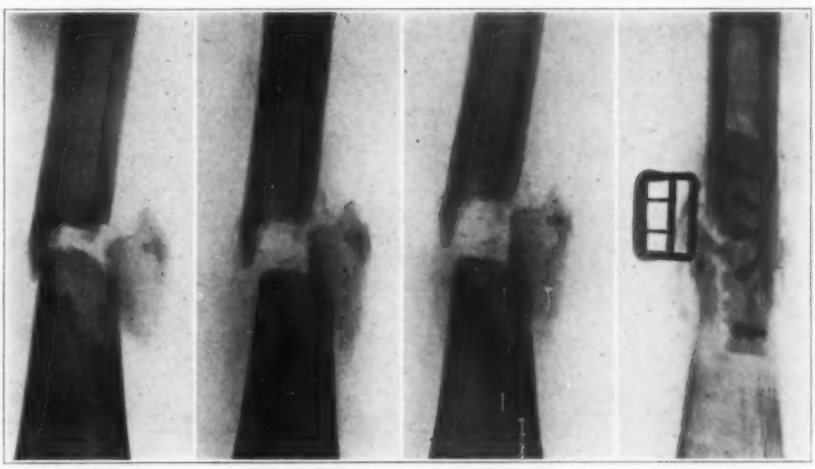

FIG. 10-A FIG. 10-B FIG. 10-C FIG. 10-D

Case 10. M. A. Delayed union.

Fig. 10-A: July 2, 1942, compound fracture of the left thigh. Adhesive traction was used.

Fig. 10-B: July 7, 1942, skeletal traction was begun. Note the position of the extruded fragment and the "open door".

Fig. 10-C: August 15, 1942, after six weeks of skeletal traction there is no union, fibrous or otherwise.

Fig. 10-D: October 19, 1942, after a sliding bone graft.

This patient also sustained a traumatic amputation of the right leg and multiple other fractures. He became ambulatory with support and artificial right leg January 1, 1943.

tures, and the evidence seen at the time of correction of malunions, it is clear that the periosteum is practically always found continuous from one fragment to the other throughout a portion of its circumference. In the vast majority of fractures, the dead space between fragments is represented by a three-sided space, the two bone ends together with a variable-sized connecting side wall of periosteum. There is, therefore, a continuous layer of bone-forming surface, or at least a continuous surface for the adsorption or deposition process. However, once the remaining periosteal wall is severed, the space between the bone ends is opened completely for the free access or ingress of soft-tissue humoral substance. From the beginning stage of original hemorrhage, through the intermediate capillary ingrowth, to the point of final fibrous tissue, the non-bone-forming fibrous-tissue phase can easily invade and persist in the dead space created by the separation. Again it is almost a universal clinical observation that bone healing remains discrete, it does not invade soft parts except as a pathological new growth.

Physiological callus formation remains strictly limited to the fracture surfaces, and never extends laterally. It also is characterized by original hemorrhage, ingrowth of capillaries, infiltration of lime salts, osteoblasts, and giant-cell osteoclasts.

Both conditions are characterized by a centrifugal force or outflow.

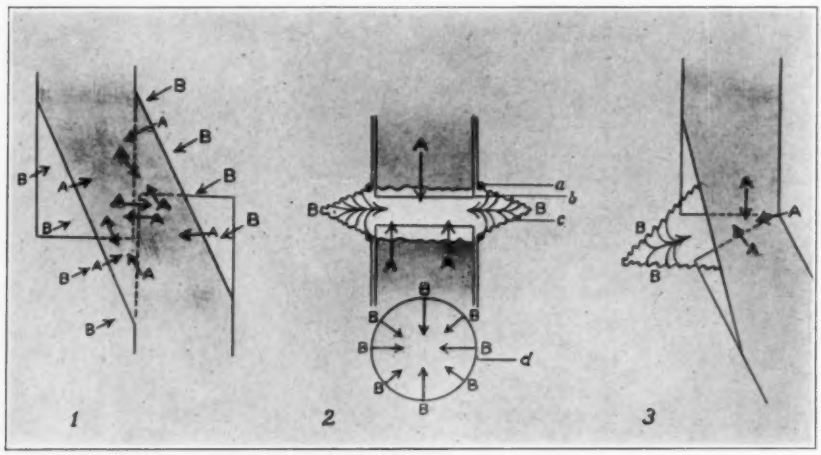

FIG. 11

1: Illustrates the usual behavior of periosteum in the usual fracture with overriding.

A: Indicates the direction of the flow of bone fluid.

B: Indicates the direction of the flow of soft-tissue fluid.

2: Shows the effects of distraction. The many-tailed arrows also indicate the flow of the soft-tissue fluid.

a: Circumferential band of callus formation,

b: Bare bone end,

c: Soft-tissue damage,

d: The short distance (radius) of a circle necessary for ingrowth of soft-tissue-repair process.

3: Shows the behavior of periosteum with a longitudinal split around a three-sided space.

Where circumferential annular rents have occurred, the free interplay of soft-tissue force and bone force is permitted. Where a segment of periosteum bridges the gap, the soft-tissue force is *shut out* along this periosteal surface defeating the ever-present threat of the invasion of the non-bone-forming soft tissue. Finally, if this is a true explanation of non-union of the type illustrated, then the possibility of this type of mechanism explaining non-union and delayed union can be applied to many other defects commonly encountered in the fracture field.

SUMMARY

1. Six cases of frank non-union are shown to have occurred as the result of the unique distraction possessed by pin reductions.

2. The irrevocable damage wrought by complete circumferential annular tears of the periosteum is shown.

3. An added factor productive of delayed union and non-union is presented.

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THE EXPERIMENTAL USES OF THE SULFONAMIDES AND OTHER DRUGS IN ACUTE PURULENT ARTHRITIS

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Conflicting reports of the efficacy of the use of the sulfonamides in acute and chronic bone infection have led to some confusion.

Hoyt, Davis, and Van Buren recently reported the successful results of treatment of a small series of cases of acute osteomyelitis with chemotherapy only. Baker in a careful study of the use of sulfanilamide in traumatic and infected wounds concluded that the drugs are valuable as surgical adjuncts, but did not replace thorough surgery.

Studies [3] on the bactericidal power of the sulfonamides have shown that only in the case of the beta hemolytic streptococcus is any one of the drugs bactericidal; and that one was sulfanilamide. Staphylococcus is inhibited by all members of the series. The best inhibitory or bacteriostatic effect was obtained by sulfathiazole.

Other drugs and therapeutic agents likewise have been credited with remarkable results,—neoarsphenamine, staphylococcus antitoxin, and bacteriophage.

The authors tried to produce osteomyelitis in the ribs of guinea pigs by producing compound fractures and inoculating the area with cultures of the staphylococcus, but as in a similar attempt reported elsewhere,[4] they were unsuccessful. They did not use the method suggested by Scheman, Janota, and Lewin, though they intend to in the near future.

Experiment One

One cubic centimeter of staphylococcus aureus hemolyticus (eighteen-hour peptone broth culture) was injected into the right knee joint of each of six rabbits.

Four of the rabbits died in three days while the other two died in five or six days. All showed evidence of staphylococcus septicaemia, and all knee joints contained tremendous amounts of pus.

Experiment Two

The injections were decreased to two-tenths of a cubic centimeter, thereby lowering the mortality while still providing enough basis for an active local infection.

This two-tenths of a cubic centimeter of the staphylococcus culture was injected into the right knee joint of each of eight rabbits. Staphylococcus phage was given intravenously to two, locally into the knee joint

TABLE I

No. of Animals	Drug	Infection
2	5 cubic centimeters bacteriophage given intravenously	4 plus *
2	2 cubic centimeters bacteriophage given locally	4 plus
2	2 cubic centimeters bacteriophage given subcutaneously	3 plus
2	No bacteriophage given to controls	4 plus

* *4 plus* represents a joint that was destroyed and was full of pus.

to two, and subcutaneously to two. Two animals were used as controls. Treatment was begun in twenty-four hours and was continued daily for five days. The animals were sacrificed thirty days after the last treatment.

Experiment Three

The same procedure was carried out as in Experiment Two except that forty milligrams of neoarsphenamine was used intravenously.

All the animals, including the controls, showed 4 plus infection.

Experiment Four

In this series five cubic centimeters of 5-per-cent. sodium sulfathiazole was given intravenously for five days. The results were the same as in Experiment Two.

Experiment Five

Staphylococcus antitoxin was given locally and subcutaneously. Again the results were the same, except that one treated animal showed no infection. The use of the antitoxin was repeated on another series, and this time all the treated animals showed overwhelming infection.

The same type of infection was produced and treated in several series of animals by the local use of 5-per-cent. solutions of neoprontosil, sulfanilamide, and sulfathiazole, the latter given in a supersaturated solution so as to concentrate as much of the drug in the joint as possible.

Every available combination was also used,—that is, sulfanilamide and sulfathiazole, given locally, orally, and intravenously, and sulfanilamide and sulfathiazole along with neoarsphenamine and in combination with antitoxin and bacteriophage, *et cetera*.

All of the animals showed tremendous local infection about the injected areas. The treated series could in no way be differentiated from the controls.

The authors' present experimental work deals with minimal local infection. The same drugs and combination of drugs are being used. These results will be reported at a later date. The work reported in this paper was intended to simulate the severe human staphylococcus infections. Incision and drainage were not carried out because of the difficulty of looking after the animals. Aspiration of swollen joints likewise was not feasible because of the thick discharge and the difficulty of using large bore needles.

CONCLUSIONS

In view of what is known to date of the action of the sulfonamide drugs, the inhibiting effect of purulent material, and of the bacteriostatic rather than the bactericidal properties against staphylococcus, the authors believe they are justified in drawing the following conclusions:

1. In cases of marked infection, the sulfonamide drugs and other therapeutic agents cannot alone be expected to control the infection.

2. Surgical procedures are as necessary today as before. The drugs are extremely valuable as adjuncts, but the authors can find no good evidence to support any contention that they can be expected to control bone and joint infections.

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THE KENNY TREATMENT FOR INFANTILE PARALYSIS

A Comparison of Results with Those of Older Methods of Treatment

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At the Country Branch of the New York Orthopaedic Dispensary and Hospital, the Kenny treatment for the early stages of infantile paralysis was first begun experimentally in the fall of 1941. In the following months, a total of forty-eight patients received this new treatment for part or all of the acute stages of the disease. This paper is a preliminary study of the early and immediate results of the Kenny technique on the signs and symptoms of poliomyelitis from the onset of the illness until the end of the first year of treatment. In comparison with other patients treated by the older methods, the "Kenny patients" seem significantly better. Final conclusions on the merits of this new treatment, however, should be determined from end results in the amount of paralysis and deformity in the years to come.

All patients in the Hospital under treatment for the acute stage and paralytic symptoms of poliomyelitis from May of 1941 to May of 1942 have been included in this study. This is a total of sixty cases divided into three groups,— (1) those having *only* Kenny treatment, (2) those receiving Kenny treatment *late* in the course of their illnesses, and (3) those having only the *older* methods of therapy. These patients were compared in August of 1942, at which time all treatment for the acute stages had been concluded for from four to ten months, and the chronic and residual symptoms of deformity and paralysis were most apparent. Many of these patients have continued a slow improvement since this comparative study was made, particularly in the group which had the Kenny treatment.

Group 1 in this investigation comprises twelve patients who received only conventional methods of early therapy, which Sister Kenny calls "orthodox" treatment,—absolute bed rest, immobilization for protection of weak and paralyzed muscles by splints and bivalved plaster casts, prevention and correction of deformities by approved orthopaedic principles, and the generally accepted system of muscle testing and training. The results from this group are listed under "orthodox treatment".

Group 2 consists of twenty-four patients who were first treated by conventional routines for some weeks or months, and then by the Kenny treatment for the remainder of their therapy for the acute stage. These have been analyzed under the heading "orthodox plus Kenny treatment".

Group 3 comprises the twenty-four patients who received *only* Kenny treatment from the onset of the disease. This therapy was started and

TABLE I

LENGTH OF TREATMENT NECESSARY IN THE ACUTE STAGE

Treatment	Group 1 Orthodox Treatment (*12 Patients*)	Group 2 Orthodox plus Kenny Treatment (*24 Patients*)	Group 3 Kenny Treatment (*24 Patients*)
Average time in splints	3 to 18 months	1 to 4 months	None
Bed rest without splints	None	1 to 7 months	1 to 4 months
Average time confined in bed	12 months	7 months	3 months
Illness before hot packs	—	2 to 28 weeks	0 to 6 weeks
Duration of treatment with hot moist packs	—	2 to 20 weeks	4 to 24 weeks
Average time in hot packs	—	8 weeks	12 weeks
Duration of hospital treatment	5 to 30 months	2 to 11 months	2 to 9 months
Average hospitalization	16 months	9 months	6 months

continued through the contagious and isolation periods by Daly, Greenbaum, and their associates at the Willard Parker Hospital. These workers had only a single article from a medical journal to guide them,[1] so the first technique was only an approximation of the true Kenny methods. However, after Sister Kenny made personal visits to these Hospitals and examined the patients, a more accurate routine was established under which the patients seemed to improve more quickly.

The convalescent periods of therapy were given at the Country Branch of the New York Orthopaedic Dispensary and Hospital at White Plains, New York, from December 1941, until the patients were discharged to their homes. Follow-up and physical therapy were continued at the Dispensary in New York City. This group is reported under the title "Kenny treatment". They received all the fundamentals of this new therapy,—bed rest in a natural position, hot moist packs to relieve muscle spasm and prevent contractures, passive motion to restore awareness, and the Kenny technique of muscle re-education to eliminate mental alienation and incoordination, and to restore muscle power.

A comparison of the early demonstrable results in these three groups of patients is given in Tables I, II, and III. This is the first report of the results in groups of patients treated by the Kenny methods to be compared with a control group receiving conventional therapy. Comparative data indicate significant clinical differences.

Table I demonstrates that patients under the Kenny treatment are confined to bed and in the hospital a shorter time than previously was necessary. The Kenny technique of hot moist packs is intensive for a period of weeks, but the final total effort, time, and expense to the hospital and patient should be much less per case than with previous methods.

Symptoms are recorded as described by various examiners on the patients' clinical charts. The greater incidence of the findings of muscle

TABLE II

SYMPTOMS FOUND AND TREATED

Symptoms and Treatment	Group 1 Orthodox Treatment	Group 2 Orthodox plus Kenny Treatment	Group 3 Kenny Treatment
Paralysis and weakness in muscles	12 patients	22 patients	22 patients
Non-paralytic abortive attacks	0 patients	2 patients	2 patients
Symptoms described by Sister Kenny			
Muscle spasm	4 patients	17 patients	24 patients
Incoordination	2 patients	14 patients	22 patients
Mental alienation	3 patients	8 patients	16 patients
Deformities developing during treatment	16	30	11
Contractures found to be causing deformity	12	24	10
Additional contractures found	6	9	3
Duration of muscle spasm (average)	Over 6 months	3 months	1½ months

spasm, contractures, alienation, and incoordination in the Kenny series is due to increased skill and experience in detecting these symptoms. Fewer contractures and deformities developed in Group III, they were less severe, and they responded more easily to specific management. In the untreated patients muscle spasm persisted from six to eleven months until replaced by contractures and often deformities.

In Table III, under "functional results" are tabulated the amounts of normal activities the patients have been able to carry on after discharge from the hospital. Patients with "excellent" results are able to follow all their usual pursuits without disability. Patients with "good" results have mild residual weakness or contractures. They attend regular school or work, but cannot engage in strenuous athletic sports or occupations. Patients with "fair" results are those who now or later may require braces or surgery for stabilization of weak limbs. Patients with "poor" results are those who require crutches or canes besides braces for satisfactory locomotion, or those patients who have deformities which will require surgical correction.

The extent of recovery of some patients under the Kenny treatment is so great that in studying the final results considerable careful judgment must be used in deciding which of the improvements in the patient's condition are due to the Kenny treatment and which would have followed from a mild or abortive attack of poliomyelitis.

CONCLUSIONS

1. Forty-eight patients with infantile paralysis in 1941 have been treated by the methods of Sister Elizabeth Kenny of Australia, with encouraging and significant results when compared with twelve patients treated by older methods.

TABLE III

COMPARISON OF EARLY RESULTS OF THERAPY

Results	Group 1 Orthodox Treatment (*12 Patients*)		Group 2 Orthodox plus Kenny Treatment (*24 Patients*)		Group 3 Kenny Treatment (*24 Patients*)	
	No.	Per Cent.	No.	Per Cent.	No.	Per Cent.
Patients with residual paralysis (muscle groups "fair" or less)	10	83	14	58	8	33
Patients with residual deformities (some with more than one)	9	75	6	25	2	8
Total number of deformities	16	—	11	—	2	—
Patients requiring braces or surgery (including temporary braces)	6	50	8	33	4	17
Estimated functional results						
Excellent	1	8	6	25	11	46
Good	3	25	8	33	10	42
Fair	4	33	7	29	3	12
Poor	4	34	3	13	0	0

2. The presence of the symptoms of muscle spasm, mental alienation and incoordination in the acute stage of the disease has been verified.

3. The important rôle of untreated muscle spasm in forming muscle contractures and producing deformities has been demonstrated.

4. Treatment by means of bed rest in a natural position, hot moist packs, passive motion, and muscle re-education has proved successful in relieving these early symptoms when given as Sister Kenny has described.[3]

5. Immobilization by casts or splints is not necessary for the protection of weak muscles or to prevent deformities, and is actually harmful in prolonging muscle spasm and preventing the use of the Kenny routines.

6. Patients receiving the Kenny treatment are more comfortable, have better general health and nutrition, are more receptive to muscle training, have a superior morale, require a shorter period of bed rest and hospital care, and seem to have less residual paralysis and deformity than patients treated by older conventional methods. The Kenny treatment is the method of choice for the acute stage of infantile paralysis.

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RECURRENT DISLOCATION OF THE SHOULDER JOINT *

A Combination Procedure. A Preliminary Report

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That the surgical treatment of recurrent dislocation of the shoulder joint is controversial is well illustrated by the number of articles on the subject and the variety of operative procedures [17] advocated for its correction. This indicates that the present end results are not entirely satisfactory.[7, 8] The recent work of Bost and Inman, and of Nicola [10] indicates that the surgical treatment of anterior dislocation of the shoulder in many instances should be more extensive than most of the operations now in use. There is considerable disagreement as to the pathology of recurrent dislocation of the shoulder. However, the studies of Bost and Inman; Nicola [10]; Bankart; and Hill and Sachs have led to a clearer understanding of these changes.

Trauma was the cause of the original dislocation in all of the authors' cases. During anterior dislocation, the head of the humerus is forced over the anterior rim of the glenoid. Depending on the severity and direction of this force, the following changes may occur:

1. Injury to the labrum glenoidale, tearing it loose from its attachments;
2. Chip fracture of the anterior edge of the glenoid;
3. Capsular tear or displacement;
4. A compression or shearing fracture of the posterolateral portion of the humeral head, caused by the digging in of the anterior rim of the glenoid.

PATHOLOGICAL AND ROENTGENOGRAPHIC FINDINGS

Although this flattening or "grooved defect" of the posterolateral surface of the humeral head was originally described by Flower in 1861, and the roentgenographic appearance by Perthes in 1906, its clinical significance had not been emphasized until the report of Hill and Sachs in 1940 and Bost and Inman in 1942. When this defect is present, the anterior rim of the glenoid, particularly with the arm in external rotation, fails to offer a bone block to prevent a recurrence of the dislocation.

The defect can be demonstrated roentgenographically by an anteroposterior view made with the arm in marked internal rotation (Fig. 1-A). The defect is wedge shaped, consisting of a flattened plateau, varying in

* Since submitting this article, the authors have learned that Captain Irving Wolin, Chicago, Illinois, performed a similar operation, August 18, 1939, using a tibial graft. His patient had a recurrent dislocation of the left shoulder five months after a Nicola operation. Roentgenograms revealed a similar compression defect and chip fracture of the glenoid as is here described.

size from 1.5 centimeters to 3.5 centimeters wide and 0.75 of a centimeter deep, with a sharp, dense medial border, a "line of condensation which is related to the size of the defect"[6]. This defect is not visualized in the film with the arm in external rotation (Fig. 1-B).

As the humeral head slides over the anterior rim of the glenoid, a chip fracture may occur, and also a tear of the labrum glenoidale, as Bankart recognized and Bost and Inman later verified. Occasionally the

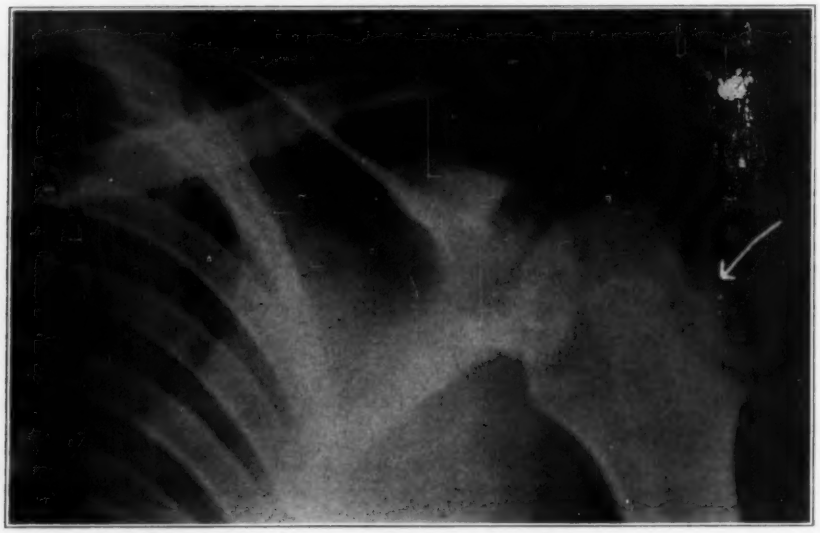

FIG. 1-A

Anteroposterior view of left shoulder in marked internal rotation, showing defect on posterolateral portion of the humeral head.

FIG. 1-B

View in external rotation. This patient had a Nicola tendon transplantation performed in August 1940 (arrow). In spite of this operation the shoulder continues to dislocate about once a month. The patient refuses further operative procedure.

labrum is so badly injured that adequate repair is difficult, and only capsular resistance to recurrence of the dislocation may be offered, with no adequate block to the sliding of the defective and flattened humeral head anteriorly over the glenoid. Nicola has recently emphasized the importance of the capsule, and has advocated exploration to determine the location of the tear, repair of this, and reinforcement with transplantation of the long head of the biceps. Since the shoulder joint is large enough to accommodate a humeral head twice the normal size, the amount of resistance the capsule offers is of questionable value.

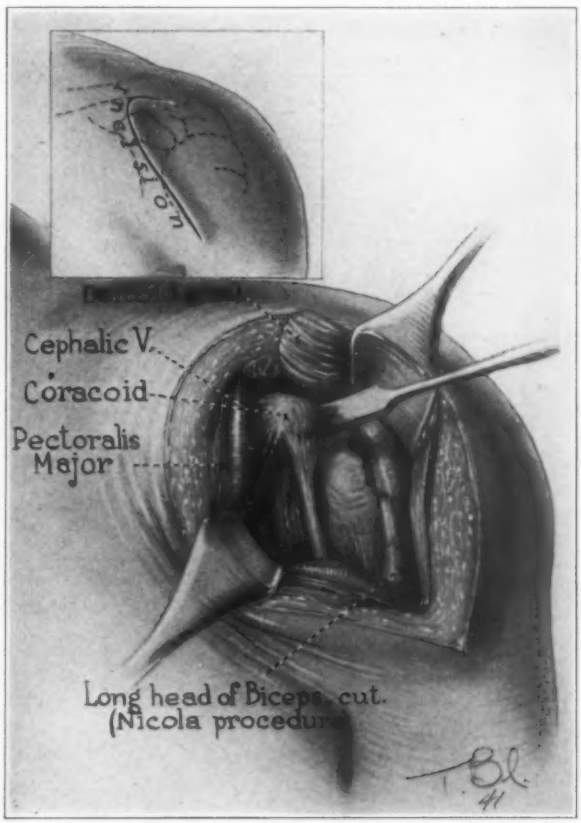

FIG. 2

In view of these considerations it was the authors' feeling that for successful prevention of recurrent dislocation of the shoulder, the defect of the humeral head, when present, must be corrected or counteracted. Their experience indicates that transplantation of the biceps tendon alone in these patients is not sufficient. The grafting of bone or the implantation of a vitallium plate over this defect of the humeral head is not feasible. It therefore seemed advisable to interrupt the matching of the humeral head and glenoid by changing the shape of the latter through the implantation of a bone shelf at the antero-inferior margin of the glenoid. Following dissections on cadavera, the following operative method was devised.

TECHNIQUE OF OPERATION

The operation is performed under gas-oxygen-ether anaesthesia. The incision (Fig. 2), a modification of Henry's for exposure of the humerus, and of Roberts' [14] for repair of acromioclavicular dislocation, is in the shape of a reversed hockey stick with the curve starting over the

lateral portion of the coracoid and extending obliquely downward for a distance of three to four inches. The deltoid is dissected from the cephalic vein and pectoralis major, and is retracted laterally, after its upper fibers have been cut from their attachment to the clavicle for a distance of about one and one-half inches. This allows exposure of the humeral head and palpation of the posterolateral portion of the head of the humerus. The long head of the biceps tendon is then transplanted through the head of the humerus in the manner described by Nicola [9], or the bicipital groove is deepened as in the Roberts' [13] operation.

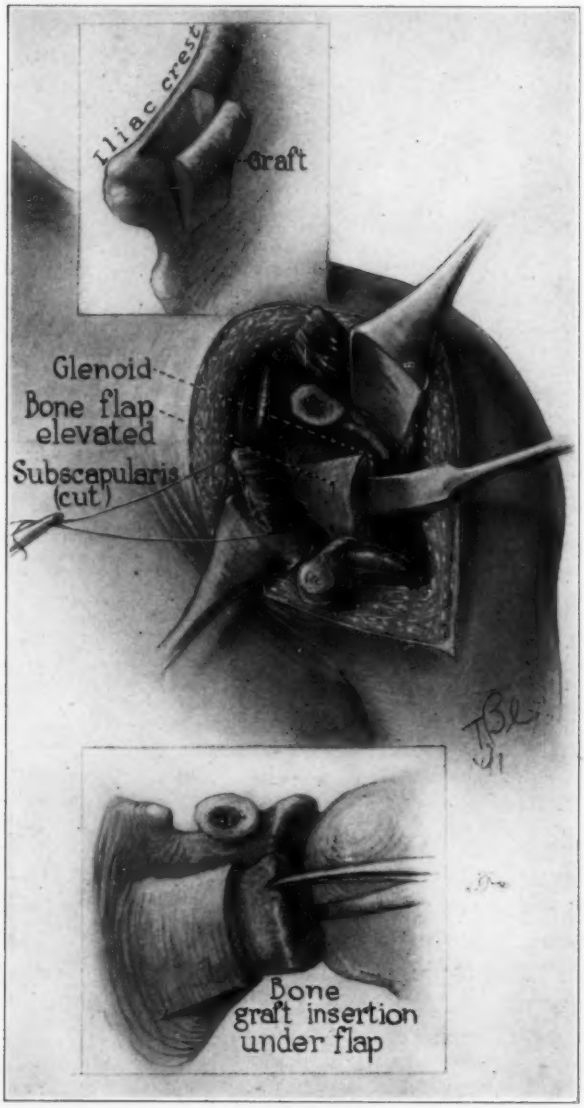

FIG. 3

With an osteotome (Fig. 3) the coracoid process, together with its muscle attachments, is freed and retracted downwards. After exposure with a blunt instrument and insertion of silk sutures, the subscapularis muscle is divided. In this manner the neck and rim of the glenoid are exposed. A curved incision is then made below the rim of the glenoid on the antero-inferior aspect, and a bone flap is elevated with the osteotome.

Through a small incision, the ilium is exposed subperiosteally and a bone graft about three-quarters of an inch by two and one-half inches is obtained. The graft is inserted under the bone flap in the neck of the glenoid at the level of the articular surface or projecting about three-sixteenths to

one-quarter of an inch beyond the rim of the glenoid. Frequently the graft is securely wedged in place; if not, it may be anchored with a suture. Closure is obtained by approximating the cut ends of the subscapularis. The tip of the coracoid with its muscle attachments is replaced, and is secured with two silk ligatures passing through drill holes at the base of the coracoid. The cut fibers of the deltoid are sutured back onto the clavicle. After approximating the deltoid and the pectoralis major, the subcutaneous tissue and skin are closed with interrupted sutures. The arm is immobilized in a Velpeau bandage for from five to seven weeks, when active motion is begun.

This operative procedure has been performed on four cases:

CASE 1. A male, twenty-four years old, dislocated his left shoulder in 1935. There was recurrence of the dislocation two to three times a month, most frequently when he reached up for an object or turned over in bed while asleep.

The roentgenograms revealed a defect in the posterolateral portion of the humeral head.

A Nicola tendon transplantation alone was done, July 3, 1941. However, there was recurrence of dislocation after this operation. Accordingly, on September 11, 1941, a shelf operation was performed. Follow-up studies four months later showed no recurrence of the dislocation, and the following active shoulder motions:

Motion	Right (*Degrees*)	Left (*Degrees*)
Abduction	180	180
Flexion	180	180
Rotation with arm at right angle, internal	80	80
Rotation with arm at right angle, external	100	70
Rotation with arm at the side, internal	60	60
Rotation with arm at the side, external	70	45

FIG. 4

Case 4. Arrow points to the site of the bone graft forming a shelf on the neck of the scapula of the left shoulder.

CASE 2. A nineteen-year-old patient was thrown from his horse against a stable wall, dislocating the left shoulder. The dislocation was immediately reduced and immobilized. However, dislocation recurred so frequently during the next five months that he was unable to carry on his normal activity.

Roentgenograms revealed a defect or depressed area, measuring two centimeters, in the lateroposterior aspect of the humeral head, and a chip fracture of the anterior rim of the glenoid.

The shelf operation combined with the Nicola tendon transplantation was done on September 3, 1941. The patient returned to his normal unusually active occupation. On May 15, 1942, eight months after surgery, check-up examination revealed no recurrence of dislocation. Roentgenograms showed the bone graft in good position. His only complaint was some "stiffness" through the whole left shoulder during cold or rainy weather. Active motions of the shoulder were as follows:

Motion	Right (*Degrees*)	Left (*Degrees*)
Abduction	180	180
Flexion	180	180
Rotation with arm at right angle, internal	78	60
Rotation with arm at right angle, external	100	96
Rotation with arm at the side, internal	80	80
Rotation with arm at the side, external	45	40

CASE 3. A male, twenty-two years old, dislocated his left shoulder playing softball. He thought that the arm was forcefully abducted and externally rotated while sliding into second base. Afterward the shoulder came out of place three or four times a month. It occurred "when asleep in bed, on changing position, playing ball, or using the arm at all."

The roentgenograms revealed a compression defect in the lateroposterior portion of the humeral head, with a small chip fracture of the inferior anterior rim of the glenoid.

The shelf operation combined with a Nicola tendon transplantation was done on September 19, 1941. The postoperative roentgenograms showed the bone graft approximately one centimeter below and medial to the glenoid lip, in good position. Seven weeks after operation the patient returned to his active occupation with the following shoulder motions:

Motion	Right (*Degrees*)	Left (*Degrees*)
Abduction	170	170
Flexion	180	180
Rotation with arm at 90 degrees abduction, internal	70	70
Rotation with arm at 90 degrees abduction, external	90	80
Rotation with arm at the side, internal	90	90
Rotation with arm at the side, external	50	25

CASE 4. This patient, thirty-three years old, dislocated his left shoulder in 1927 playing football. The mechanism of dislocation could not be recalled. There was a history of recurrence of the dislocation with the mildest of trauma and even during sleep.

Roentgenographic studies revealed a defect on the lateroposterior aspect of the humeral head.

On July 22, 1942, a bone graft from the ilium was inserted on the edge of the glenoid in combination with a Nicola transplantation of the biceps tendon (Fig. 4). The patient returned to his normal duties. Follow-up examination three months later showed no recurrence of dislocation. The circumference of the upper arm was eleven and one-half inches on the right, and eleven inches on the left; and of the forearm ten and one-quarter inches on the right, and nine and three-quarters inches on the left. The shoulder motions were as follows:

Motion	Right (*Degrees*)	Left (*Degrees*)
Abduction	180	180
Flexion	180	160
Rotation with arm at right angles, internal	70	70
Rotation with arm at right angles, external	75	35
Rotation with arm at the side, internal	75	70
Rotation with arm at the side, external	120	80

DISCUSSION

Several procedures for prevention of recurrent dislocation of the shoulder by the insertion of a bone graft into the neck of the scapula have been reported. These, however, have not been combined with transplantation of the biceps tendon. The successful transplantation of a wedge of bone from the tibia into the neck of the glenoid was published by Eden in 1920. Phemister, as reported by Speed, performed this operation with success on a number of patients. Speed has also reported the insertion of a bone peg at the antero-inferior margin of the glenoid with good results. In a paper published in 1940, Orell of Stockholm noted that Hybbinette, in 1917, used a graft from the ilium to form a bone block on the neck of the glenoid with excellent results. However, search of the medical literature has failed to reveal a description of this procedure. The authors' surgical approach is a modification of that described by Bankart in 1938 and used by Bost and Inman in their cases.

The crest of the ilium has definite advantages,—its curve corresponds to that of the glenoid; its superior surface is smooth and forms a perfect buttress; and it affords a thicker graft than does the tibia.

This shelf operation combined with the Nicola or Roberts' tendon transplantation is indicated when there is marked damage to the bone or soft tissues of the shoulder. It is advisable (1) when there is a flattening of the posterolateral portion of the humeral head; (2) when there is a deformity or chip fracture of the anterior edge of the glenoid; (3) when such damage of the labrum glenoidale is present that adequate repair by the Bankart operation is impossible; (4) when thinning of the capsule is such that adequate suture cannot be done; and (5) after failure of previous surgery. The authors have not performed the bone graft alone, but have used it in combination with the Nicola procedure. During the dissection, adequate exposure of the humeral head is obtained, so that transplantation of the biceps tendon may be done easily.

Although this combined operation is long, no difficulty has been encountered either with shock or infection. The patients are up on the fourth postoperative day. After immobilization in a Velpeau bandage for five to seven weeks, the shoulder rapidly regains motion and strength. Since it is recognized that it is too soon to determine the end results in these four cases, this operative procedure for recurrent dislocation of the shoulder joint is presented as a preliminary report.

The shelf operation prevents the matching of the flattened posterolateral surface of the humerus with the glenoid. By placing the bone

graft on the neck of the glenoid, the glenoidal rim is widened, support is afforded the labrum glenoidale, the defect of the glenoid from chip fracture is corrected, and a bone block is presented to the humeral head.

SUMMARY

1. This operative procedure for recurrent dislocation of the shoulder has been performed with good results on four patients. In combination with transplantation of the biceps tendon, a shelf is constructed on the antero-inferior margin of the neck of the scapula using a bone graft from the ilium.

2. The indications and advantages of this procedure are noted.

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THE CHOICE OF THE ANAESTHETIC AGENT AND THE CARE OF THE PATIENT IN RELATION TO THE ANAESTHESIA IN ORTHOPAEDIC SURGERY *

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Anaesthetic agents are among the most commonly and widely used drugs, and the numerous addenda to the anaesthesia armamentarium in the last twenty years have made possible choosing the ideal agent for the individual patient and operation. In orthopaedic surgery, the procedures necessitating anaesthetization of patients are numerous and of various types and severity, and every effort should be made to keep the anaesthetic portion of the operative risk at a minimum.

The orthopaedic surgeon can best decide what condition a patient should be in when anaesthetized for a given orthopaedic procedure, and in selecting the anaesthetic agent, he should evaluate the patient and the operation *in toto*. A twenty-minute procedure may require a sixty-minute anaesthesia, because time for the induction of the anaesthesia must be included, and this may vary from three to thirty minutes, since the response of a patient to an anaesthetic is a personal variable. Often, too, the anaesthesia is as difficult to administer and maintain as the operative procedure is to perform, and forcing the anaesthetic in such cases is a false economy. Frequently it is advisable to use an anaesthetic which can be administered safely for a long period of time rather than one with a limited time of administration, so that the operator will not be rushed.

The anaesthetics used in orthopaedic surgery include the inhalation, local, spinal, rectal, and intravenous agents. The details of the characteristics and techniques of administration of these agents will not be discussed, because they are more properly in the realm of the anaesthesiologist than of the orthopaedic surgeon.

The volatile inhalation anaesthetic agents include chloroform, ether, vinethene (divinyl ether), and ethyl chloride. All give good muscle relaxation. None are explosive in ordinary anaesthetic mixtures, but are inflammable. Chloroform is now infrequently employed, because of the high incidence of permanent liver and renal damage associated with its use. With ether, the induction and recovery from the anaesthesia are relatively slow, but it can be used safely for almost any type of patient and for long anaesthesias. Vinethene and ethyl chloride permit rapid induction and recovery from the anaesthesia. Vinethene is frequently associated with permanent liver damage when inhaled for more than one-half hour, and should not be given patients with decreased liver function. It

* Read before the Annual Meeting of The American Orthopaedic Association, Baltimore, Maryland, June 3, 1942.

causes considerable mucus secretion, and atropine should be given before the anaesthetic. It can be used satisfactorily alone for short procedures, as an induction agent for ether anaesthesia, or to supplement for short periods local, spinal, or intravenous anaesthesia. Ethyl chloride preferably should not be given to patients over twelve years of age; it should not be administered for more than a few minutes; it is frequently associated with laryngospasm; and it may be followed by cardiac arrest. It is suitable for use alone for short procedures, or as an induction agent for ether anaesthesia.

Gaseous inhalation anaesthetic agents often used are nitrous oxide, ethylene, and cyclopropane; and of these, nitrous oxide alone is neither explosive nor inflammable, and can be used in the presence of electrical apparatus. All three agents permit easy, rapid induction and recovery, and all have a low incidence of untoward postanaesthetic reactions. In general only fair muscle relaxation is obtained.

Nitrous oxide is a valuable agent for short procedures, as an induction agent for ether anaesthesia, and to supplement spinal, local, or intravenous anaesthesia. Proper premedication with morphine or a barbiturate permits an increase in the amount of oxygen which may be given with nitrous oxide for the same anaesthetic levels. It is contra-indicated in cardiovascular disease.

Ethylene can be administered with more oxygen than can nitrous oxide; and more muscle relaxation can be produced with it than with nitrous oxide. The preanaesthetic medication with ethylene should be the same as with nitrous oxide.

Cyclopropane permits the use of greater amounts of oxygen and gives greater muscle relaxation at the same anaesthetic levels than nitrous oxide, but the anaesthetist should be experienced in the special technique of administration with the "closed system" required, and the particular reactions of patients to this anaesthetic. An objection to the use of cyclopropane for orthopaedic operations is that it may be associated with increased bleeding.

Local and spinal anaesthetics have a restricted use in orthopaedic surgery because they permit operative procedures only in limited regions, and the technique of regional and nerve blocks requires considerable skill. Apprehensive patients do not react well to major procedures performed with these agents, and the possibility of a sensitivity of the patient to the drug used should not be disregarded. Spinal anaesthesia is contra-indicated in debilitated patients and those in shock.

Rectal anaesthesia is well established as a basal anaesthesia. A barbiturate may be used. Avertin gives a satisfactory basal anaesthesia, but should not be used for the aged, the very young, or patients with long-standing septic conditions, overwhelming infections, diabetes, anaemia, or shock.

Intravenous anaesthesia has had an increasing popularity during the last few years, the most commonly used intravenous anaesthetic agent

now being pentothal sodium. The choice of this intravenous anaesthetic should be determined on the basis of the characteristics of the drug. Pentothal sodium is a barbiturate, and hence causes in patients the same reactions as other barbiturates. Anaesthesia with this agent is essentially an "acute extreme barbiturate sedation". With pentothal sodium, muscle relaxation is not so great as with certain other anaesthetics. The sensitivity of patients to the drug is an individual one, and a dose which brings about a satisfactory anaesthetic level in one person may be lethal or insufficient for another. Similarly, the recovery period from the anaesthesia is determined by the reaction of the individual patient to the drug, as with any barbiturate. Hence, some patients will be somnolent for a relatively long time after the anaesthesia, and this is of particular importance when pentothal sodium is administered to ambulatory patients. The period of postanaesthetic somnolence is often prolonged by the early postoperative administration of morphine. Recovery from pentothal-sodium anaesthesia seems to be hastened by the use of intravenous fluids during and after the anaesthesia.

Pentothal sodium preferably should not be used for patients with generalized arteriosclerosis or the aged who often have postanaesthetic disorientation. Small children require more of the drug proportionately than adults; and the added difficulty of performing satisfactory venipunctures on children makes them poor subjects for pentothal-sodium intravenous anaesthesia.

It is now well established that there is no contra-indication to the use of pentothal sodium for patients with decreased liver function, or those receiving any of the sulfonamide drugs. It should not be used for patients with severe anaemia.

Preanaesthetic medication is important when pentothal sodium is used. Laryngospasm and respiratory depression are not rare during the induction of the anaesthesia, and atropine given before the anaesthetic reduces the incidence of these reactions. Morphine given preanaesthetically reduces the amount of pentothal sodium required for the anaesthesia. When possible, a barbiturate, administered orally or rectally the night before and again one to two hours before the anaesthetic, reduces the amount of pentothal sodium required. Oxygen or a mixture of equal parts of oxygen and nitrous oxide administered throughout the anaesthesia gives a smoother anaesthetic course, and less pentothal sodium is needed. In general, a 2.5-per-cent. solution of pentothal sodium in sterile distilled water has been found most satisfactory.

Pentothal sodium is advocated for patients with head injuries on whom orthopaedic procedures must be performed, because it is associated with little nausea or vomiting, and has little effect on the blood pressure and intracranial pressure. It is valuable, also, for anaesthetization of patients with epilepsy, since it is a barbiturate.

On the Orthopaedic Service at The Johns Hopkins Hospital, pentothal-sodium intravenous anaesthesia has been found effective for most ortho-

paedic procedures. It can be given to the same patient frequently without apparent deleterious effects, one patient having received it ten times in as many months, with from two to four weeks between each administration, and having had no apparent untoward reactions.

The immediate anaesthetic mortality with any of the agents is low, and is approximately the same with each. A recent study revealed no deaths due to the anaesthetic agent among patients undergoing orthopaedic procedures in The Johns Hopkins Hospital during the last ten years.

It is beyond the scope of this paper to discuss the broad subject of preanaesthetic preparation and postanaesthetic care of the patient. Some factors have been considered in relation to the individual anaesthetic agents, and only a few other outstanding problems will be mentioned. Orthopaedic patients may be classified in regard to the "anaesthetic risk" as:

1. Patients with no demonstrable systemic disease;
2. Patients with infections of the respiratory tract;
3. Patients with cardiovascular disease;
4. Patients in shock;
5. Patients with other types of complications.

Studies have shown that among patients with infections of the respiratory tract, even the low-grade chronic types of infection, there is a greater incidence of acute infections of the respiratory tract after spinal anaesthesia than after inhalation anaesthesia; and the incidence of acute infections of the respiratory tract is markedly increased after any inhalation or spinal anaesthetic given such patients. Hence, elective orthopaedic procedures requiring anaesthesia should be postponed until any existing infection of the respiratory tract has been cleared up.

There is a lower incidence of such postanaesthetic reactions as atelectasis, pneumonia, or death from aspiration when patients are observed by trained individuals during the recovery from the anaesthesia than when they are cared for by persons who may not be trained to recognize the need for, or to employ such measures as suction to clear the air passages.

In general, orthopaedic patients in the "poor-risk" group and those in shock do not react so well to major operative procedures performed under local or spinal anaesthesia as under general anaesthesia. Especially in patients undergoing emergency orthopaedic procedures is it important to consider the details of preanaesthetic medication, the choice of the anaesthetic, and the judicious use of intravenous fluids.

In orthopaedic surgery, because the anaesthetic agents which may be used alone or in various combinations make available anaesthesia suitable for almost any procedure on any patient, both the operative procedure and the patient's course can be made easier and more uneventful by the constant recognition of the essential part that the anaesthesia plays in the whole picture of an operation, and by close cooperation between the orthopaedic surgeon and the anaesthetist.

THE CARE OF THE KNEE FOLLOWING EXCISION OF A MENISCUS

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During the present national emergency, the Orthopaedic Section of the Surgical Service of an Army Station Hospital has furnished a very excellent opportunity for the study and management of traumatic injuries, and, in particular, of injuries to the knee joint. The expression of George Peele recorded in the literature of the sixteenth century, "a man at arms must now serve on his knees", is still applicable considering the number of knee injuries.

In the past thirteen months 441 patients have been seen in the clinic, with complaints of swelling or pain or both, or instability of a knee following an injury to the joint. One hundred and forty-three have been admitted to the Hospital because it was thought they had a torn or dislocated meniscus. Seventy knees have been surgically explored. In fifty-eight of these, the operation consisted in the removal of the medial meniscus, and in ten, of the lateral meniscus (six were cystic, three were disrupted, and one was a discoid cartilage). In one of the other two cases, preoperatively diagnosed as a derangement of the internal semilunar cartilage, the menisci were found to be normal, and osteochondritic bodies, flaked off from the articulating surface of the medial femoral condyle, were found and removed. These had not been apparent in the preoperative roentgenograms. The other patient, in whom no cartilage derangement was found, had a torn anterior cruciate ligament with a fragment dislocated, so as to "lock" the knee. One of the explorations of the lateral meniscus revealed a discoid cartilage which had been suspected preoperatively.

Most of the injuries occurred as a result of twisting the knee, usually during strenuous activity such as sports of various kinds, marching, jumping, etc., although a few (seven) resulted from blows or falls.

The anterior third of the medial meniscus was involved in ten cases, the anterior and middle third in twelve, the middle third in thirty-two, the middle and posterior thirds in one, and the posterior third in two. In one case there was no injury, but the meniscus was hypermobile. Table I gives the frequency of the types of injury.

Twenty-one patients with injuries to the medial meniscus were first seen within four days of the original injury, sixteen of these either the day of the injury or the day after; twelve were first seen from ten days to six months after injury; one, eleven months after; and twenty-four, from one

TABLE I

SIXTY CASES OF DERANGEMENT OF THE MEDIAL MENISCUS SURGICALLY EXPLORED.

Type of Injury	No. of Cases
Bucket-handle tear. (In one instance the handle was torn in the middle.)	19*
Longitudinal tear. (In three instances the tear was in the periphery and in one it was associated with osteochondritis.)	15
Transverse tear, usually incomplete. (In one instance it was associated with splitting of the cruciate ligament.)	5
Dislocation (medial 7*, lateral 2†)	9
Fraying. (In two instances it was also hypertrophied.)	3
Marginal tear	3†
Irregular tear	2
Tear of the anterior attachment	1
Peripheral detachment with osteochondritis of the under surface of the patella	1
Hypermobile meniscus	1
Anterior third detached and folded back on the middle third	1
No cartilage injury, but anterior cruciate ligament torn	1
Loose flakes from the medial femoral condyle	1

* In one case a bucket-handle tear was associated with a medial dislocation. It has been listed under both injuries.

† In one case a lateral dislocation was associated with a marginal tear. This case has been listed under both injuries.

to fifteen years after injury. The date of the original injury was unknown in two.

Of the ten with injury to the lateral meniscus, one was first seen five months after the original injury, and nine, from three to seventeen years after the original injury.

Twenty-nine per cent. of the patients had locking of the knee as a symptom.

The authors' technique of meniscectomy has not varied from standard accepted procedures; a tourniquet has been employed and the usual anterior incision has been used. In the majority of the operations for the removal of the medial meniscus, they have left the posterior attachment rather than make an additional incision, and none of the patients has had any subsequent difficulty attributable to this. In five cases, where a simple bucket-handle tear was found, and the remainder of the cartilage was in good condition, only the bucket-handle portion has been removed. In removing the lateral meniscus, a combined anterior and posterior approach has usually been employed. In sixty-two cases spinal anaesthesia has been used (procaine hydrochloride); in six, ether inhalations; and in two intravenous sodium pentothal. Spinal anaesthesia is favored because of the greater relaxation provided.

A conservative régime has been followed, and approximately 50 per cent. of the patients whose swelling, tenderness, and disability subsided within four to eight weeks with rest and physical therapy, have been re-

turned to duty without operation. These patients presented no instability and it was thought that their lesions were in the peripheral vascular area of the cartilage. Twelve were subsequently readmitted, following additional injuries, with definite signs of instability, and operation had to be performed.

Keeping the soldier patient under constant hospital observation until he has completely recovered has been particularly valuable for follow-up, and for the development of a proper rehabilitation regimen. The patient may be very concerned about losing time from his work for what he considers a minor disability in a class with a sprained ankle, so he may conceal it from his officer, and hobble around for weeks before reporting to the Dispensary. Unfortunately, when he does report, some of the Field Medical Officers may be inclined to allow him to continue at limited duty, thereby greatly reducing the chances for spontaneous healing. If operation is finally advised, he may rebel at the long period of hospitalization. Of course, he can be ordered to have the surgery done, but that is rarely necessary and almost never desirable.

The problem of the patient with an injury to the meniscus received before induction or enlistment into the Army is far greater. He has had his "trick knee" for several years, and has been to his family doctor with it a number of times. It always recovered, so he has been able to "get by" in civilian life with only an occasional recurrence of symptoms. Frequently, he has been advised by someone—an osteopath, chiropractor, athletic trainer, or occasionally by his family physician—never to allow anyone to operate on his knee. As this adviser is known and trusted by him, and the member of the staff is a total stranger, it is not surprising that he holds back for some time before consenting to operation. Many fear a stiff knee, postoperatively. To overcome this attitude, the symptoms are allowed to subside in an orthopaedic ward where the patient can become acquainted with men who are in practically all stages of postoperative convalescence. Then he is discharged to military duty with the explanation that his symptoms will probably recur as soon as his knee is put under some abnormal strain, and that when they do, if he will return, his knee will be fixed for him. Rarely is more than the barest explanation offered, in the way of "sales talk", as to what is to be done, and the results to be expected. Instead, the other ward patients are depended upon to be the "salesmen". Unless a knee remains "locked", the patient is allowed to return to full duty when all symptoms have subsided. When his symptoms recur, he usually comes in promptly and asks to have the operation performed. Employing such tactics, it has not been necessary to invoke the military regulation by which a soldier can be compelled to submit to the operation or face a trial by court martial, or to use this as a threat.

The authors have emphasized the tactics of gaining the confidence of the patient because they feel that the postoperative course is very largely dependent on the patient's willingness to carry out active physical therapy

in spite of discomfort. In their opinion, those patients, who have had certain mental reservations and fears as to the outcome, and who have been operated upon, have had a noticeably slower return of function. Certain of the active physiotherapy procedures used postoperatively are definitely painful, and the patient with a lack of confidence in his doctor or in the ultimate outcome of his condition is much less likely to carry out these exercises.

Probably the greatest psychological hurdle is the first weight-bearing. Postponing the issue by the use of crutches for a few days is time wasted, as the change from crutches to unaided walking is just as much of a crisis as getting out of bed. Once the patient gains confidence that his leg will support his weight, his progress is good for a time. Since he is not sick, and only very slightly crippled after the second week, as far as ordinary walking is concerned, the prolonged hospital stay becomes something of a problem in morale. A bit of ward police duty added to the active physiotherapy is a welcome break to what might otherwise be a monotonous day to the patient. In line with this policy, patients are frequently assigned as monitors to direct the exercises of other patients who are a week or so behind them in their convalescence, and they usually go at this with enthusiasm and considerable intelligence gained from their own experience.

The final psychological barrier to hurdle is the return to full military duty. There are two extremes in the patients' reactions to this. One may be afraid that he is losing out by being absent from his organization and so he attempts to hurry his doctor's decision to return him to duty by being overactive. The other secretly hopes that he will have some disability that will allow him to retire honorably from combat service, and so neglects the care of his knee as much as possible. It is here that competitive spirit among the patients is of value, and the ones making satisfactory progress tend to make life a bit unhappy for those who do not carry out the prescribed exercises. It is the authors' impression that other patients spot "gold brick" tendencies several days before the doctors are able to discern them.

An approach is made to this problem very early, by encouraging patients who have made a complete recovery and are on field duty to return to the ward as visitors. A more direct approach is made later by discussing with the patient some of the duties he will have to perform, and attempting to devise exercises simulating these duties for him to carry out in the last week or so of his hospital stay. As an incentive to increased cooperation, some of the men are discharged a week or so earlier than they were told would be the case, so as to accept a furlough prior to returning to duty. It is amazing how much more rapidly tone will return to a quadriceps, if the patient knows that he can get a furlough if he is able to carry out a certain exercise by a given time.

The postoperative care of operations on the knee joint follows no rigid pattern, but is readjusted daily by the member of the staff following the progress of the case. The fundamental point is that the patient is

seen daily by the same staff member from the time of his operation until he is able to do full military duty. This, the authors believe, is responsible for a more rapid return of full function.

When sterile preparation of the extremity is begun forty-eight hours prior to operation, the patient is instructed in the mechanism of contracting the quadriceps muscle while lying flat in bed. It is much easier to make him understand this mechanism at this time than it is postoperatively when such manoeuvres are painful. He is returned to bed from the operating room with a pressure dressing on the completely extended knee, and no splint is used. Placing a pillow under the knee is forbidden. The pressure is relieved six to ten hours after the operation by splitting the circular dressing on the side opposite the incision, allowing expansion, and then applying adhesive straps. During the first night he is permitted out of bed to urinate if he so desires. The next day, he is encouraged to get up, but is not ordered to do so. If there is only a minimal distention of the joint, quadriceps contractions in bed are started on the first or second postoperative day. Considerable time is spent with the patient in demonstrating how this procedure is accomplished, and why it is insisted upon. He is usually much more cooperative in carrying out such exercises when he understands that it is important, even though it is accompanied by discomfort or actual pain.

From the third to the fifth day, if the patient shows a desire to get out of bed, the original dressing is removed and a small patch dressing covered by a circular elastic bandage is applied. Skin sutures are removed on the fifth or sixth day, because of the psychological advantage gained. The relief from pain caused by suture pull on motion of the joint outweighs the occasional minor mishaps such as small openings in the skin or the formation of a small superficial hematoma. There have been no gross disruptions of the wound, but one herniation of a joint capsule occurred, which had to be repaired subsequently. After removal of the sutures, walking is urged, with an elastic bandage encircling the knee, and efforts at complete active and passive extension are encouraged. The vigor of the urging is inversely proportional to the amount of fluid in the joint, and the psychological attitude of the patient. The elastic bandage is not employed for over ten days. It has not been necessary to aspirate any of the knees in this series, and air or oxygen injections have not been employed.

After ten days the patient is given routine daily exercises. For five minutes out of every two hours, while awake, he is required to contract the quadriceps rhythmically and for five minutes more, to extend the knee forcibly by pressing down with his hands on the thigh just above the joint with the heel resting on some solid object such as the foot of the bed frame. A variation of this manoeuvre frequently used is to have the patient stand with the knee forcibly extended (using the hands to aid in this if necessary), and contract the quadriceps for five minutes. These exercises are fundamental in preventing that slight limitation of extension

and quadriceps weakness often seen as a residual disability following knee-joint surgery, even though ideal anatomical healing has been obtained.

Each day the knee is examined, and the patient is required to demonstrate the amount of extension and flexion possible, and the tone he can muster in his quadriceps. The importance of the manoeuvres is reiterated frequently, because no knee can recover until this muscle is restored to good functional condition.

When the quadriceps presents good tone, and complete extension is closely approached, climbing stairs is added, and the proper method of raising the body weight from the lower to the higher step with the affected leg is emphasized. When this exercise becomes easy, the patient is encouraged to step up into an ordinary straight chair with the involved leg, and to lower himself slowly back to the floor. This is a particularly valuable procedure because similar activity will be necessary on return to duty in order to mount the various vehicles used in the present army.

Regaining full flexion of the knee only occasionally becomes a problem. In such a case, the patient sits on the side of his bed with the leg hanging off the bed. Then, with gravity aiding flexion, and sometimes, with the addition of a few pounds of weight to the foot, he actively flexes and extends the knee as far as possible.

During the final week of hospitalization, the patient is put through full knee bends as used in army calisthenics, for ten times, five times per day, and the "chair stepping" exercise for a similar period. In addition, he is sent on hikes about the hospital grounds. (A few patients have carried out running and other athletic procedures on the hospital recreation field with sufficiently gratifying results to encourage the authors to try them out on others who are to be discharged to unusually rigorous duty.) If no swelling or pain develops with this, and if complete extension is obtained with each normal step, the patient rarely has any trouble with the most exacting military duty.

Neither the location nor the type of injury has had any appreciable effect upon the length of the postoperative hospitalization.

The average time from operation to return to duty in forty-five completed cases has been fifty days for the patients with injury to the medial meniscus. This does not include the patient with injury to the cruciate ligament, whose hospitalization was extended to 188 days because of spondylolisthesis. Seventy-one and one-third days was the average hospitalization for those with injury to the lateral meniscus. It should be kept in mind that these patients return to duties even more strenuous than is encountered in most heavy industrial work. Their period of hospitalization is comparable to the longer time a civilian surgeon would allow before permitting his patient to return to active athletics instead of to an office or factory occupation.

The results in the sixty cases of injury to the medial meniscus have been good in forty-two and fair in four. The results are not known in

two cases, and twelve patients are still hospitalized. Three of the patients with fair results have some atrophy of the quadriceps, and one has slight anterior and posterior instability.

The results in the ten cases with injury to the external meniscus were good in seven and fair in two. One patient is still hospitalized. Of the two with fair results, one has a moderate residual atrophy of the quadriceps and weakness, and the other has mild residual atrophy of the quadriceps and weakness.

Heat and massage have been frequently employed with these patients for the relief of pain, and whirlpool baths have been used late in their convalescent period, but it is believed that daily active physiotherapy started promptly after surgery, and performed by the patient himself under careful supervision, is the key to proper postoperative care of knee operations.

SUMMARY

From a study of seventy patients who have been operated upon for injury to a meniscus, the authors conclude that careful supervision of daily active physiotherapy, which is started immediately after the operation and is carried out by the patient himself, is the best method of obtaining perfect joint function. The methods of obtaining quadriceps tone and a full range of joint motion are discussed.

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FRACTURES OF THE NECK OF THE METACARPAL

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Fractures involving the region of the metacarpal neck commonly result in permanent deformity and disability when treated by methods of extension. Invariably the fracture unites with dorsal angulation, the capsule of the metacarpophalangeal joint contracts, and serious limitation of flexion of the corresponding finger develops. In 1938, Jahss demonstrated the significant rôle of the capsule of the metacarpophalangeal joint in the reduction of fractures of the metacarpals, and described a rational method based on these considerations. In the author's series of twenty-two cases treated by the method of Jahss, uniform excellent end results have been obtained.

Conduction anaesthesia was employed in the majority of cases in preference to local infiltration or general anaesthesia. For fractures of the fourth and fifth metacarpals, satisfactory anaesthesia can be obtained by infiltrating about five cubic centimeters of a 2-per-cent. novocain-adrenalin solution around the ulnar nerve in the groove behind the internal epicondyle. For the second and third metacarpals, the median nerve is blocked just beneath the palmaris longus tendon at the wrist, and this anaesthesia is supplemented by infiltration of the sensory branches of the radial nerve running subcutaneously in the region of the anatomical snuff box. Complete sensory anaesthesia rapidly develops within ten minutes, and lasts for approximately two hours. Occasionally a transitory motor paralysis may develop, but this disappears within thirty minutes.

After satisfactory anaesthesia has been obtained, impaction of the fragments is thoroughly overcome by direct manipulation. This is of paramount importance, and the method is doomed to failure if it is disregarded. At the conclusion of this step, the fragments must be freely movable. Overriding, if present, must be corrected by traction. A padded plaster-of-Paris cast, incorporating a thin layer of felt over the dorsum of the hand, is applied to the forearm, wrist, and hand, and extends distally as far as the fracture site, with the wrist maintained in slight extension. This fixes the proximal fragment. When the plaster is thoroughly set, the injured finger is flexed to 90 degrees at the metacarpophalangeal and proximal interphalangeal joints, the distal interphalangeal joint remaining in extension. To avoid rotational deformity, the remaining fingers are then flexed, and the injured finger is normally aligned. It must be remembered that the fingers in flexion point obliquely to the region of the tubercle of the scaphoid [2]. A thin strip of felt, slightly

* Service of H. Theodore Simon, M.D.

wider than the finger, is applied over its dorsal surface from the tip to the fracture site. A second smaller piece is interposed between its volar surface and the cast. A plaster-of-Paris splint, twelve inches in length, one-quarter of an inch in thickness, and slightly wider than the finger, is prepared and placed over the dorsal surface of the distal and middle phalanges of the flexed finger, and incorporated in the volar surface of the forearm cast by several turns of plaster bandage. Gentle upward pressure is then applied over the dorsal surface of the proximal interphalangeal joint and middle phalanx until the deformity is overcome, and the reduction is maintained, while an assistant draws the splint snugly over the finger and knuckle and incorporates it into the dorsal surface of the cast by several more turns of plaster. Upward pressure is continued until the splint is completely set, during which interval the splint is molded to the contours of the finger.

Since many of these cases are seen several days after the injury, considerable oedema of the hand may be present at the time of reduction. To prevent displacement, the plaster cast must be changed when swelling subsides. Alternatively, reduction may be delayed until the oedema disappears with appropriate therapy.

Immobilization is maintained for approximately three weeks, during which time active exercises of the remaining fingers are practised regularly and persistently. Upon removal of the cast, it is surprising to note that

FIG. 1-A

Typical fracture of the neck of the fifth metacarpal.

FIG. 1-B

Perfect reduction of the fracture after manipulation and immobilization.

extension of the metacarpophalangeal joint rapidly recovers and is often complete within twenty-four hours. Motions of the distal interphalangeal joint are not affected. Recovery of extension of the proximal interphalangeal joint is usually slower than the others. Occasionally, limitation of the terminal degree of extension occurs. The explanation lies in the fact that when this joint is flexed to 90 degrees, the lateral slips of the extensor apparatus are displaced away from the mid-line and with the pressure of the cast become adherent to the lateral aspects of the capsule of the proximal interphalangeal joint. However, if active exercises are persisted in, recovery is the rule.

RESULTS

Of the twenty-two cases in this series, twenty involved the metacarpal neck and two were of the head proper. Deformity recurred in two cases involving the neck. In the first case, a second reduction and an additional fourteen days of immobilization were necessary. The second patient suffered a refracture after a period of seventeen days of immobilization. In the process of positioning the hand for roentgenograms immediately following the removal of the cast, the technician inadvertently fully extended the finger, producing immediate pain and deformity. Unfortunately the patient was not seen again for several weeks, at which time examination revealed the typical malposition. However, function of the finger was excellent. Two cases in this series were compound fractures. One, a gunshot fracture of the fifth metacarpal neck and distal portion of the shaft, was reduced and immobilized following débridement and

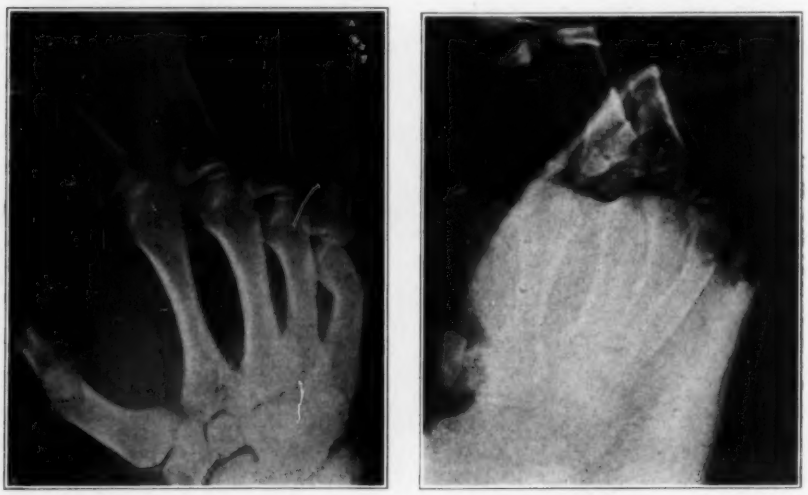

FIG. 2-A FIG. 2-B

Fig. 2-A: Typical "punch" fracture of the neck of the fifth metacarpal.
Fig. 2-B: Following manipulation under ulnar-nerve block, excellent anatomical reduction has been obtained. Note the first section of the cast extending to the fracture site.

FIG. 3-A

FIG. 3-B

FIG. 3-C

Fig. 3-A: Compound fracture of the head and neck of the fourth metacarpal resulted from a knife blow. After débridement and internal fixation with very fine chromic sutures, the wound was closed, and the finger was immobilized with the metacarpophalangeal joint at a right angle and the interphalangeal joints in moderate flexion.

Fig. 3-B: Roentgenogram was taken immediately following removal of the cast. Note the excellent position.

Fig. 3-C: Lateral view was taken immediately following removal of the cast. Note that extension at the metacarpophalangeal joint is almost complete despite three weeks of immobilization at a right angle. The proximal interphalangeal joint remains flexed, and recovery in this joint is slower than in the others.

suture of the wound. Despite slight rotational deformity and ulnar angulation, which was difficult to prevent because of the marked comminution, a good functional and anatomical result was obtained. The second case resulted from a knife blow, and involved the head and neck of the fourth metacarpal (Figs. 3-A, 3-B, and 3-C). Débridement, internal fixation with fine chromic sutures, and suture of the wound followed by immobilization in the position of full flexion of the metacarpophalangeal joint and moderate flexion of the interphalangeal joints, to prevent capsular contraction at the metacarpophalangeal joint, produced an excellent anatomical and functional end result. The remaining sixteen patients with fracture of the neck of the metacarpal obtained uncomplicated excellent end results with no residual deformity and normal motion of all the finger joints.

In both cases involving the metacarpal head proper, reduction could not be completely obtained despite numerous attempts. It is doubtful if these fractures can be reduced by any method. However, immobilization by the method described prevented capsular contraction, and excellent functional results were obtained.

In no case did a pressure sore develop over the dorsal aspect of the middle phalanx or the proximal interphalangeal joint. They are only produced by excessive pressure in reduction, and this is unnecessary if the fragments have been thoroughly disimpacted initially.

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THE ETIOLOGY AND SURGICAL TREATMENT OF INTRACTABLE PAIN ABOUT THE FOURTH METATARSOPHALANGEAL JOINT (MORTON'S TOE) *

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The purpose of this paper is to discuss the condition known as Morton's toe, to report eleven consecutive cases of this disease which have been treated by operation, and to show that in each case a definite cause of the pain was found. From these cases and from other facts to be mentioned, it will be shown that the clinical syndrome known as Morton's toe is caused by a tumor involving the most lateral branch of the medial plantar nerve.

A typical case of Morton's toe is characterized by severe lancinating pain originating in the region of the fourth metatarsophalangeal joint. This pain is shooting in character, and may travel up the calf of the leg as far as the knee. The pain comes on in paroxysms of varying intensity, and in many subjects is accompanied by an almost uncontrollable desire of the victim to remove his or her shoe. The disease occurs in men and in women in the proportion of about six to ten.

This condition, first described by Morton of Philadelphia, has been and remains today a not uncommon ailment. Its cause has not been generally recognized, although the literature abounds with speculations as to the etiology. From the author's study of this disease, he has been forced to the conclusion that in some instances metatarsalgia involving other bones than the fourth may be due to the same cause as Morton's toe. In his experience, conservative measures cure the common variety of metatarsalgia, while the syndrome known as Morton's toe fails to respond to such measures. Since the difference in pain experienced by a patient with metatarsalgia and by a patient with the typical Morton's syndrome is as marked as the difference between the pain complained of by a person with a subungual exostosis and that complained of by a person with a subungual glomus tumor, the patient with Morton's toe is liable to drift from doctor to doctor seeking immediate and permanent relief from his agony.

Morton in his classic paper first published in January 1876 states, "In these cases the pain has been localized in the fourth metatarso-phalangeal articulation; in several instances it followed at once after an injury of the foot, in others it was gradually developed from pressure, while in others there was no recognized cause".

* Presented at The Chicago Surgical Society, December 1941; The Clinical Orthopaedic Society, Chicago, Illinois, January 18, 1943; and the Boston Orthopaedic Club, March 22, 1943.

In this same paper Morton describes the operation he first performed on March 22, 1873.

In his writings on this condition, Morton ascribed the cause of the pain to the pinching of the lateral plantar nerve that supplies the fifth toe and the lateral portion of the fourth toe. He thought the pain was due to the fact that the joint of the fifth metatarsal bone is so posterior to that of the fourth that lateral pressure brings the head of the fifth metatarsal and the little toe into direct contact with the base of the first phalanx, and the head and neck of the fourth metatarsal bone. This mechanism was given by Morton as the cause of pinching of the branches of the lateral plantar nerve. As this paper will show, it is not the branches of the lateral plantar nerve that are involved, but the branches of the most lateral division of the medial plantar nerve that supply the medial portion of the fourth toe and the adjacent surface of the third toe (Fig. 1).

Morton and others of his day attempted to relieve the pain by hollowing out a depression in the shoe for the fourth metatarsal head, padding the foot, and trying firm soles and wide shoes. These measures failed in the severe form of this trouble.

Since Morton's time, surgical relief of this syndrome has been either by amputation of the toe or resection of the metatarsophalangeal joint. The cause of the condition has remained obscure.

The first patient in the au-

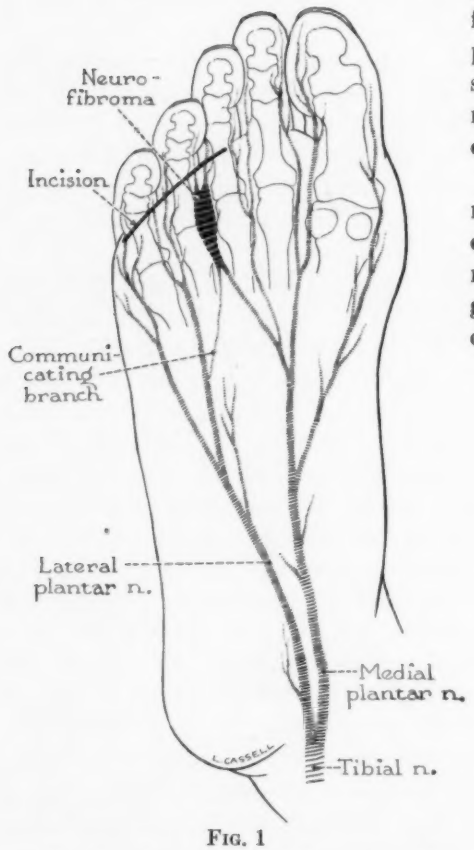

FIG. 1

Showing the anatomy of the parts. The incision shown is the one first used. Note that the location of the tumor is farther forward than the metatarsal heads.

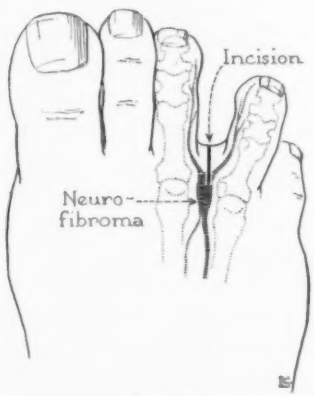

FIG. 2

Showing the location of the tumor and the type of incision that is preferred. The incision should extend more proximally than is shown.

thor's series was operated upon in June 1935. Since then ten other patients have had the operation performed. In each instance the author was able to demonstrate and remove a tumor which was always in a definite and constant location.

PATHOLOGY

Of the twelve tumors removed from eleven patients, five have had microscopic study, and appear to be either neurofibromata or angioneurofibromata. Grossly they are fatty and soft on the outside, and firm, white, and fibrous as the center is approached. In the center the plantar nerve is embedded. This bears out the statement of MacCallum,—namely, "The tumors which actually appear in the course of the nerves are usually derived from the supporting structures and are sometimes called false neuromata or neurofibromata. A fibroma is a tumor composed of tissue which resembles more or less closely one of the many types of normal connective tissue. Some fibromata are extremely soft and loose in texture; others are dense and hard. They occur almost anywhere in the body and are frequently multiple. They arise most commonly in the skin, fasciae, and in the intermuscular tissues, about the joints or in connection with nerves. A neurofibroma is then really nerve tissue embedded in fibrous tissue which may even spread apart the nerve fibers".

FIG. 3

On the left is a normal fourth digital nerve taken from a fresh specimen. On the right is a tumor of the fourth digital nerve from the foot of Mrs. E. H.

A number of pathologists have studied sections from these tumors. Agreement amongst these men has not been forthcoming. Some of these tumors are thought to be neurofibroma and others resemble glomus tumor. Further study of these tumors is being undertaken in an attempt to classify them accurately.

The largest tumor removed was from the right foot of a woman of forty-five years. This tumor measured two centimeters long, one and three-tenths centimeters wide, and about five-tenths of a centimeter thick. It was preserved in formalin and when split open had a small cystic area in its center. Through this cavity the nerve fibers were seen to be passing to and from the tumor mass.

The gross appearance of these tumors is shown in Figure 3.

Undoubtedly the most enticing explanation of a tumor arising in the region of the fourth metatarsal head would lie in some relation to trauma or irritation of the nerve. This may be true, but it should not be accepted until proved. The fact that neurofibromata of this nature arise spontaneously at many places in the body must be kept in mind. Once

the tumor has developed between the third and fourth toes, the location and the anatomical fact that the fourth nerve is more firmly held down against excursions of the toe than other plantar nerves may produce favorable conditions for pressure against the tumor. Conversely, as in one of these cases, it is possible that tumors may arise at times between the other metatarsal bones, but, because of the local anatomy and local application of pressure, these tumors may only infrequently give rise to pain of a severe nature. Further, because of this anatomical variation, conservative treatment should be more efficient in these cases than in the ones with tumors between the third and fourth toes.

The author considers the type of incision he first used, where the sole of the foot is reflected, to be far inferior to the web-splitting approach. With the plantar incision, local anaesthetic is more difficult to use, and it is more painful to administer. The exposure is more awkward because of the excessive amount of metatarsal fat and the free bleeding that occurs in the sole. The wound is slower to heal and weight-bearing is delayed.

Once the location of the tumor is fixed in the operator's mind, the web-splitting type of approach should prove most satisfactory. The tumor is more distal than one would believe it to be. It lies plantarly just at the level of the bases of the proximal phalanges, and not between the metatarsal heads (Figs. 1 and 2).

Since it first occurred to the author that all cases of Morton's toe might be due to a tumor involving the lateral branch of the medial plantar nerve, he has made a careful review of the literature on this subject. No textbook that he has encountered mentions a tumor as the cause of this condition. If he has overlooked a paper calling attention to this fact, the authors of the textbooks have been guilty of the same oversight.

To the author's knowledge, the first and only paper ever to bring forth this fact was written by Betts of Adelaide. Since both Betts' work and the author's had been without knowledge of the other, it was gratifying to note that he reports ten consecutive cases with findings identical to the cases presented here. In a personal communication Betts states: "I did my first operation for fibroneuroma, or Morton's toe, in November 1931, and have performed it on increasing number of cases since. Without adding up records, I must have personally done 25 to 30 of them, and my local colleagues have also done a small number".

Betts states in his paper that there is diminished sensation over the adjacent surfaces of the fourth and third toes. The author has not tested sensation in all of his cases as, unfortunately, it had not occurred to him to do so. Betts feels that the anastomosing branches which make up the fourth plantar nerve surround the short flexor of the fourth toe in such a way as to limit the nerve in following the toe through its complete range of dorsal extension. In this way the nerve is more liable to trauma and irritation. Betts exposes the tumor through a longitudinal incision on the plantar surface of the foot. This incision has not and should not give trouble.

Only one of the eleven patients in this series gave a history of definite injury initiating the pain. All the others were wearing or had worn low-heel oxfords or Girl-Scout shoes, had done innumerable exercises to strengthen the feet, and had had applied to the shoes all types of metatarsal pads, metatarsal bars, and double soles without definite relief. The fact is, that Morton's toe is definitely a condition requiring surgery, and permanent cure is gained by resection of the tumor.

The loss of sensation in the toes after resection of the tumor with the nerve is so trivial that no patient in this series has yet complained of this fact.

The tumor can at times be palpated between the third and fourth toes, in the region where the web joins the sole of the foot. If the toes are dorsally extended, the index finger is placed in this location, and a circular motion with firm pressure is carried out, one at times may feel a mass which crepitates and initiates severe pain in the foot similar to the pain of which the patient is complaining.

SUMMARY

Morton's toe is a painful affliction of the foot which is often resistant to conservative treatment. It is caused by a tumor involving the most lateral branch of the medial plantar nerve. Careful palpation will usually reveal the tumor which lies high in the web between the third and fourth toes, and if symptoms justify it, excision of the tumor should be done.

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A SELF-ADJUSTING FOOT-PIECE FOR PREVENTING OR CORRECTING EQUINUS DEFORMITY WHEN TRACTION IS APPLIED TO A LOWER EXTREMITY

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In the application of traction to overcome shortening or to correct deformity of an extremity, it is frequently desirable to have a constant pull in one direction and a secondary variable force in the same or another direction, without changing the direction or the amount of the constant pull.

Physicists have established the following fundamental force relations:

1. If two forces F_1 and F_2 act upon a body, their total effect is represented by the diagonal R of a parallelogram of which the two sides represent F_1 and F_2. (See Figure 1*B*.)

2. In order to balance the effect of two such forces as F_1 and F_2 an equilibrant E must be applied to the body. E is equal, opposite, and collinear with R. (See Figure 1*B*.)

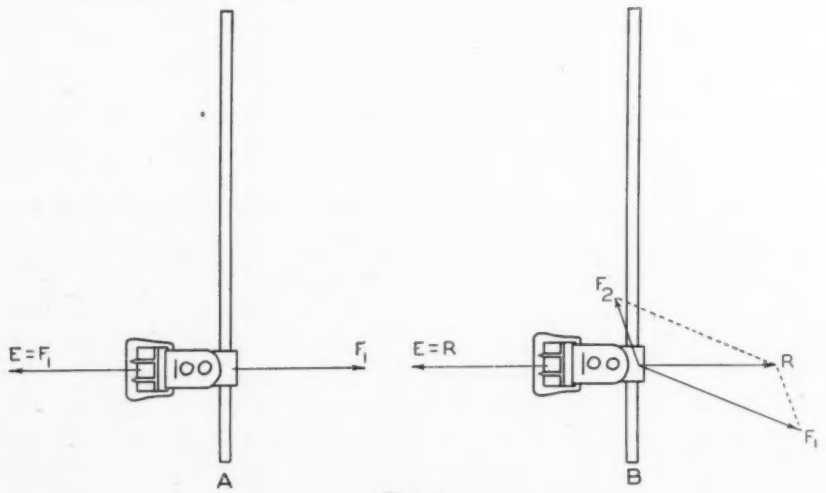

FIG. 1

A: Here a tractive force F_1 is applied to a foot-piece and is balanced by the force E (attached to the buckles and applied to the patient's leg by adhesive).

B: Here a secondary force F_2 has been added; the resultant R of these forces is the diagonal of the parallelogram formed by F_1 and F_2; in order for the adhesive force on the patient's leg to keep the same direction and magnitude, the direction of F_1 must be altered and its magnitude increased, as compared with *A*.

Because of the above force relations it has been difficult to incorporate in leg traction a foot-piece which prevents equinus deformity and allows active motion of the ankle joint without changing the direction of the tractive force or disturbing the relationship of the tractive apparatus to the extremity. Therefore, attempts were made to design a stirrup based on the following force relations:

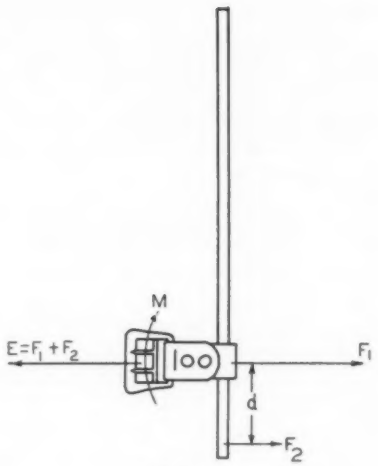

FIG. 2

Fig. 2. Shows the same tractive force F_1 applied to the foot-piece as in Figure 1*A*, and a parallel secondary force F_2 applied a distance d from F_1. The adhesive force E now remains correct in direction but is increased to F_1+F_2, while a moment F_2d is now applied to the foot-piece and is balanced by the moment M applied by the patient's foot.

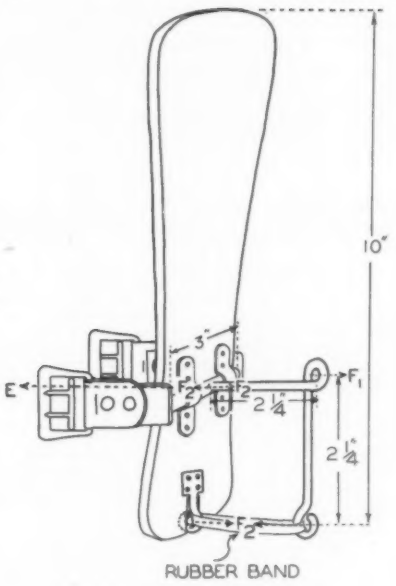

FIG. 3

Fig. 3. The attachment and foot-piece are shown assembled, with the primary tractive force F_1 balanced by the adhesive tractive force $E=F_1$. Since the force F_2 is applied entirely within the system, the desired moment on the patient's foot is produced through the freely movable foot-piece by suitable adjustment of the rubber band without affecting the tractive force F_1 or the adhesive force.

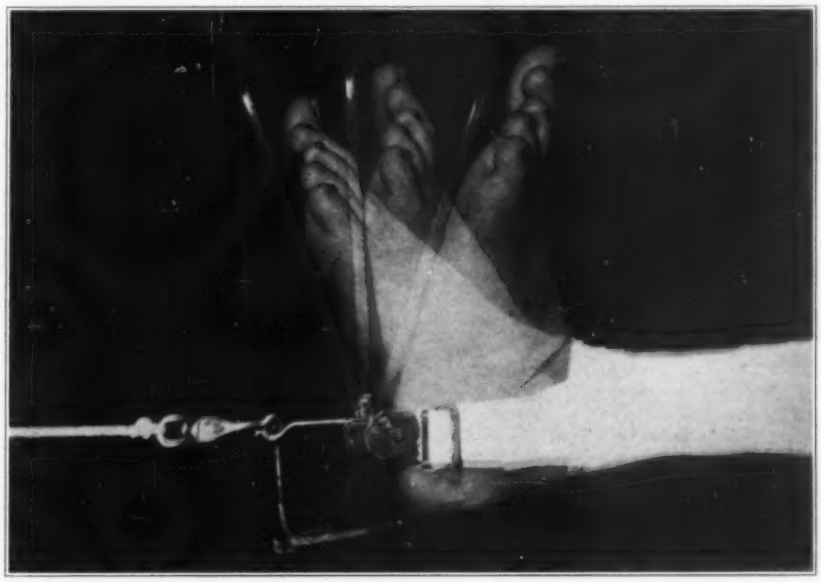

FIG. 4

A triple exposure composite picture showing active flexion and extension of the ankle without loss of foot support and without disturbance of the tractive force.

When two equal, opposite, and parallel, but not collinear, forces are applied, a moment or twisting effort results. This moment is measured by the product of one of the forces by the distance between them. Thus, in Figure 2, if F_1 and F_2, distance d apart, be applied to a body, balance is produced by the equilibrant $E = F_1 + F_2$ plus a resisting moment $M = F_2 d$.

Figure 3 shows the assembly of a foot-piece and an attachment for applying the forces F_1 and F_2 to the foot-piece under the action of the fixed tractive force F_1 (applied by a weight on a cord passing over a pulley) with a secondary pull F_2 added to the system being absorbed by a rubber band: Since the force F_2 is applied entirely within the system, the tractive force $F_1 = E$ is independent of the tension in the rubber band.

The apparatus can be made in any machine shop, is inexpensive, and is all in one piece. It allows active flexion and extension of the ankle, and, during periods of rest, supports the foot. In those patients where force is desired to correct the pre-existing equinus deformities, the amount of the force can be varied by changing the number or the size of the rubber band.

This spreader has been used as a substitute for the old-type foot-piece, and has been found to be satisfactory. It can be stated that the foot-piece allows active motion without disturbing the traction, gives support to the foot in all positions of extension and flexion of the ankle, and is comfortable.

ASEPTIC NECROSIS OF THE LUNATE BONE

A Case Report with a Study of the Pathological Changes

BY FRANCIS B. ROTH, M.D., NEW YORK, N. Y.

From the Laboratory Division of the Hospital for Joint Diseases, New York

Kienböck, in 1910, gave impetus to the study of lesions of the carpal lunate bone now often reported as Kienböck's disease. The clinical aspects of the condition have been well described since that time, but the pathology has received comparatively little attention.

Baum, in 1913, seems to have been the first to have studied the histological picture. Axhausen, in 1924, supplied a firm foundation for the belief that the essential pathology is that of an aseptic necrosis. Subsequent histological descriptions [3, 4, 5, 6, 9, 10, 11, 12, 13] are almost all in harmony with this latter point of view.

The following case is reported in an effort to contribute further to an understanding of the pathology of the lesion.

CASE REPORT *

The patient, a white male truck driver, was seventeen years old when he fell on his outstretched right hand in 1938. Application of a padded wooden splint for three weeks relieved the pain in the wrist, which had followed the fall. Thereafter, he was symptomless until shortly before he came to the Hospital in September, 1941, when roentgenograms of the wrist revealed an abnormal lunate bone (Fig. 1-A). A plaster-of-Paris cast to immobilize the wrist was put on for three months. Some months after removal of the

FIG. 1-A

FIG. 1-B

Fig. 1-A: September 2, 1941. The contour of the right lunate bone has been altered by the depression of the radial half of its proximal articular surface. A fracture line is present on the deep surface of the depressed fragment. Two small, irregularly rounded rarefied areas appear toward the wrist joint articulation. The density of the bone is on the whole increased. (The lateral view shows a decrease in the short axis of the bone.)

Fig. 1-B: April 29, 1942. Compared to Fig. 1-A rarefaction has increased centrally and density has increased peripherally. The contour of the bone shows progressive alteration from the normal.

* The history is presented through the courtesy of Frederick M. Marek, M.D.

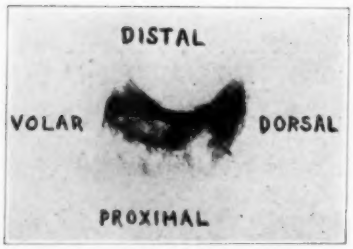

FIG. 2-A

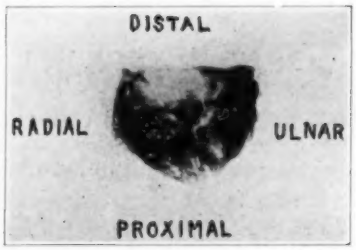

FIG. 2-B

Fig. 2-A: Lateral roentgenogram demonstrates decreased density of the proximal portion and part of the central portion, and generally increased density of the distal part of the bone. A fracture is visible on the distal surface.

Fig. 2-B: Anteroposterior view, taken with the x-ray tube tilted obliquely in the axis of the arm, demonstrates a fracture line running from the proximal to the distal aspects, and having a branch extending out to the radial side.

plaster, the patient lifted a heavy weight, and pain in the wrist recurred. In April, 1942, the lunate bone showed more advanced alterations (Fig. 1-B). The wrist was now slightly enlarged and tender over the lunate, but there was no local heat or redness. Wrist motion was painful and limited to about 30 degrees of dorsiflexion and 5 degrees of palmar flexion. Adduction and abduction of the wrist were normal.

Excision of the lunate bone on May 1, 1942, was followed by primary wound healing. A rapidly increasing range of painless wrist motion was subsequently observed.

Pathological Findings

The lunate bone was compressed in its short axis, and its proximal and distal articular surfaces were somewhat irregular, each presenting a crease that ran generally in a dorsovolar direction. After roentgenograms had been taken (Figs. 2-A and 2-B), the specimen was decalcified and sectioned into five parallel blocks for serial study.

Much of the superficial articular cartilage was found slightly modified, as evidenced by swelling of the lacunae of surface cells, fibrillation, fraying, and the presence of occasional spaces created by the fusion of several lacunae. These degenerative changes were more pronounced on the proximal than on the distal articular surface. A few small cystic areas filled with detritus lay deeply situated in the articular cartilage. Portions of the provisional line of calcification were absent. Cleavage planes (fractures) in the cartilage appeared in several places. Corresponding to the macroscopic creases, there was a complete fracture of each articular surface. Beneath the fractures in the cartilage, there was regularly a loss of bone support.

No segment of the lunate was free from aseptic necrosis. Necrotic trabeculae (containing many microfractures), necrotic marrow, and bone dust were found in the greatest proportion, relative to living tissue, in the proximal and central areas of the bone. In these places, the spongiosa was replaced by fibrous scar, which contained a few fragmented trabeculae and a little osteoid tissue. In contrast, at the distal aspect of the bone there was a tendency for the relationship of degenerative and regenerative changes to be reversed. Here osteoclastic and osteoblastic activity was often pronounced, and the fibrous tissue was usually loosely meshed and vascular. Between the dorsal and volar regions of the lunate, there was no appreciable difference in the relative amounts of viable and dead tissue.

Where the necrotic trabeculae were overlaid by osteoid or fiber bone, a mosaic-like pattern was often manifest. In many regions of active regeneration, thickened and crowded trabeculae were found. New bone was formed mainly on a skeleton of necrotic trabeculae, but it also arose by metaplasia within connective tissue. Cartilage formation was still less prominent. One fair-sized bit of mixed hyaline and fibrocartilage ap-

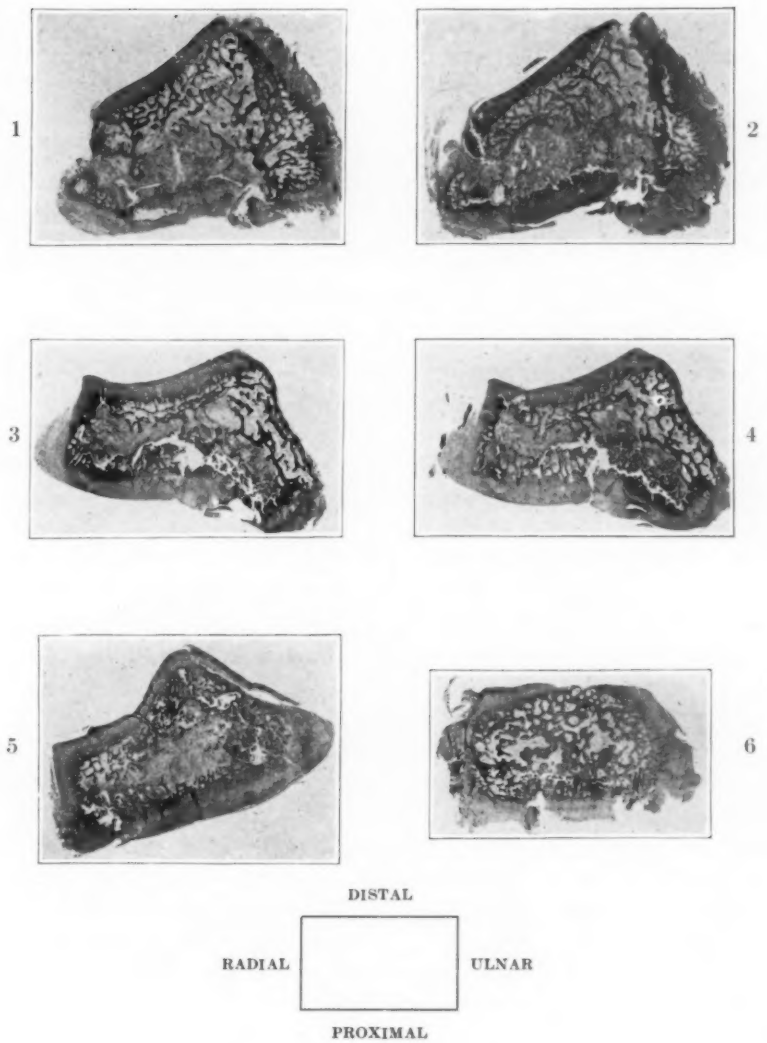

FIG. 3

Serial sections of the excised lunate bone (× 2½). Compare with Fig. 2-B, and note the fractures in the cartilage, the collapse and fibrous-tissue replacement of the spongiosa, and the tract of granulation tissue entering at the radial aspect of the bone. On the whole, the proximal and central areas of the lunate are the most modified.

peared centrally and toward the radial side of the bone, and a few much smaller bits arose elsewhere. Both new-bone and cartilage formation were particularly noted in contact with vascular connective tissue.

Occasional small focal hemorrhages, with well-preserved, red blood cells in them, and numerous hemosiderin-laden phagocytes lay scattered throughout the sections. A tract of granulation tissue entered at the dorsoradial aspect of the bone, also sending a small pannus onto the distal articular surface. The pannus overlay a small area of superficial erosion of the articular surface. There was no evidence of inflammatory disease anywhere in the affected bone.

A correlation of the preoperative roentgenograms with the pathological findings showed that the former indicate in only a limited way the extent of the necrosis, fractures, and fibrous scarring. One can see, furthermore, that the small, roundish areas of rarefaction (so-called "cysts") correspond to areas of fibrous tissue and cartilage within the lunate; and that the increased peripheral density (so-called "sclerosis") corresponds in part to a peripheral thickening and crowding of trabeculae, but mainly to the presence of considerable calcareous bone dust.

COMMENT

Pathological changes are not always so widespread as they were in this case. The proximal portion of the bone, which has been recognized by several observers as being especially prone to destruction, may be the only portion involved.

The etiology of the aseptic necrosis has usually been thought to be traumatic, and the condition ascribed specifically to initial fracture of the lunate bone or to tearing of the blood vessels that enter it. Less attention has been directed to non-traumatic causes of vascular insufficiency as possibilities; and in particular to reflex vasomotor constriction (Leriche), embolic occlusion [1], endarteritis obliterans [13], and thrombosis. Kienböck's disease, which has developed without a history of trauma after phlegmon of the hand [13] or after scarlet fever [10], is of particular interest.

Whatever the ultimate causes of the pathological changes in the specimen studied here, the sequence of events may be traced with a fair degree of certainty. It seems clear that aseptic necrosis set in before the other alterations that are now evident. Mechanical forces then evidently produced a gradual collapse of the fragile osseous tissue. Eventually, revascularization advanced from the dorsal aspect of the lunate and ramified extensively within the bone. Organizing and destructive processes became intertwined. Developing in the wake of microfractures and microhemorrhages, there were ingrowing buds of granulation tissue, with phagocytic cells enveloping necrotic debris in one place, with bone and cartilage formation in another, and with fibrous tissue developing still elsewhere.

If these processes had not been interrupted by the surgery, the dense scars would have precluded an even relatively complete restoration of the spongiosa; the distortion of the external contour of the bone would in all likelihood have increased; and progressive degenerative arthritis would almost certainly have been added.

It follows, therefore, that excision was the treatment of choice in this case. Indeed, it appears that excision without undue delay is usually called for, when roentgenographic examination shows a lesion involving much of the bone. If the lesion is a small one confined to the proximal portion, perhaps a trial of conservative treatment is justifiable. The central point of non-operative care would then seem logically to be immobilization for protection of the carpus.

SUMMARY

In a case of aseptic necrosis of the carpal lunate, a pathological examination of the excised bone showed extensive aseptic necrosis, collapse, and invasion (especially of the proximal portion) by vascular fibrous tissue. The articular cartilages were modified, and there were evidences through the bone of ununited fractures. In the wake of these changes, a secondary (degenerative) arthritis was developing. While in this case, a substantial portion of the lunate was affected, there are other cases in which the involvement is less widespread.

Excision is the treatment of choice, unless the lesion is small and limited to the proximal portion.

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METAL HIP JOINT. A CASE REPORT *

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A report of the following case seems justifiable because of its unusualness. After searching the literature, no report of a similar case can be found. The patient was observed over a period of eight years, and during this time several operations were performed, the last one being the most interesting.

The patient, a negro male, aged forty-six years, and weighing approximately two hundred and fifty pounds, was first seen in September 1934. He had non-union of a fracture of the neck of the right femur. The fracture had occurred fifteen months previously. He suffered severe pain and walked with difficulty by using crutches. Instead of doing a reconstruction operation, or a bone-grafting operation, it was decided to try to secure union by nailing the fragments together and drilling holes up through the neck and into the head to allow revascularization of the head and the fracture line.

FIG. 1

September 26, 1940. Preoperative roentgenogram showing healed fracture of the femoral neck. The nails have been removed. The large bone graft has been absorbed. A pathological fracture may be seen through the lower part of the cystic giant-cell tumor of the trochanter.

* This case was presented to the Columbia Medical Society of Richland County, South Carolina, December 14, 1942, and has been reported in *The Recorder* of the Columbia Medical Society, VI, 12, December 1942. It is contrary to the policy of *The Journal* to reprint material, but, since this publication is not available to many of the readers of *The Journal*, an exception has been made in this case.

FIG. 2

Showing sections of the tumor. The extent of the bone involvement was approximately eight by four inches.

The operation was performed, and three Moore, adjustable, stainless-steel nails were inserted. Four days after the operation this large man got up and walked about the ward without permission. He was proud of the fact that he could walk. He wanted to "show-off". He was cautioned against weight-bearing and overuse of his hip, for it was feared that the fragments would not reunite, but he continued to bear some weight on the injured hip from this time on. The fragments were held well together with the nails, and in spite of weight-bearing solid bony union did result, with no pain and with good function of the hip joint.

In February 1936, he began to complain of some pain in the hip. On examination a large cyst was discovered in the upper end of the femur in the region of the greater trochanter. On reviewing the original roentgenograms it could now be determined that a small cyst had been present at the time of his injury. This cyst, which had escaped detection previously, had increased in size. Operation was performed, the cyst was curetted, and the cavity was filled with bone chips. Microscopic section revealed the pathology to be a giant-cell tumor. Deep roentgenotherapy was administered, and the maximum dosage was given over a considerable period of time. At the time of this operation, even though a large cystic area was present in the trochanter, it was found that there was solid bony union of the previous fracture through the neck of the femur. The nails were no longer necessary, and so were removed. Improvement occurred following the curetting operation and deep roentgenotherapy, pain was relieved, and the patient got about with more or less normal function of the hip joint. (The authors have motion pictures to demonstrate his condition at that time.)

Approximately two years later there was a recurrence of pain, and roentgenograms showed further enlargement of the cystic area. Again roentgenotherapy was instituted, and the cyst was curetted. Hemorrhage during the operation was profuse and almost uncontrollable. It was feared that the patient might expire on the table. A large bone-grafting operation was performed by removing approximately ten inches of the upper end of the right fibula and grafting this across the upper end of the femur and down into the shaft. In addition, numerous bone chips were removed, and the cavity of the cyst was packed with these chips. An uneventful convalescence followed, and soon the patient was up and about, using his hip well, and with no complaint of pain.

Approximately two years later the cystic degeneration returned, and a pathological fracture occurred. Roentgenotherapy was again administered, and the fracture was

treated by bed rest and skin traction. Union in good position was obtained, and there appeared to be some healing of the tumor region. Later, the tumor again began to increase in size, and on re-examination in September 1940 a large cystic mass approximately the size of a grapefruit was found in the upper end of the femur. The cortex of the bone was very thin, and it was realized that another pathological fracture would soon occur.

By this time, every conservative means of treatment had been exhausted, and the tumor continued to enlarge in spite of every effort to control and eliminate its growth. The question then arose as to whether the limb should be amputated at the hip joint, or whether no treatment should be offered. In the latter event, the patient would have to resign himself to pathological fracture and very likely malignant degeneration of the tumor, with metastasis and death. Amputation at the hip joint would be a very serious undertaking in so large a patient.

FIG. 3

December 16, 1941. Roentgenogram taken fifteen months after operation shows vitallium model embedded in a large mass of new-bone formation. Union is solid, and motion of the hip joint is free and painless.

In an effort to do something for him, it was decided to resect the entire tumor region and to replace this portion of the bone with a metal appliance made in the form of the natural bone, and having in it various loops through which the various muscles and tendons could be attached, so that some reasonable postoperative function of the hip might be expected. Apparently no one had ever had the opportunity previously to replace such an extensive amount of bone as this case demanded. Calculations were made from roentgenograms of the bone, wax models were fashioned and from these models a mold was made, and a vitallium model of the upper end of the femur was finally produced. The appliance was about twelve

inches long. It had a smooth, rounded head to fit into the acetabulum, and there were loops for muscle attachments to the upper end. The lower end of the appliance was fashioned so that it could be slipped over and be bolted to the lower fragment of the femur. One of the authors (H. R. B.) had for some time been interested in metal replacements, and had replaced the head of the femur with vitallium. He supervised the construction of the model.

Operation was performed under spinal anaesthesia on September 28, 1940. It was realized that the shock of operation would be severe, and for that reason blood was prepared and administered prior to, during, and after the operation. A long lateral incision was made from the crest of the ilium to just above the knee. The femur was divided in half with a Gigli saw, and the upper portion, including the tumor, was removed by subperiosteal dissection. Great, large blood vessels and blood sinuses, some as large as the little finger, were encountered. Hemorrhage at times was profuse, almost uncontrollable. Many large packs were used. The dissection was continued up underneath the periosteum, the capsule of the hip joint was dissected free, and finally the head was removed from its socket by division of the ligamentum teres. When an attempt was made to fasten the vitallium appliance to the lower end of the femur, it was found that it was too small and would not slip over the bone. The bone had to be reduced in size, and the outer cortex was chiseled away. It developed that this was a serious mistake. Following removal of the hard cortical bone, there was little remaining strength in the soft more cancellous portion, and after the appliance had been slipped over the end of the bone and bolted into place, it was realized that the bone very likely would break as a result of the strong muscle pull. The head of the appliance fitted well into the acetabulum. Passive motion of the hip could be carried out in almost a normal manner. The capsule of the hip joint which had been dissected away was sutured, the muscles and tendon attachments about the trochanteric region were fastened to the appliance by suturing their ends through the metal loops provided. The deep fascia was closed, helping to hold the appliance securely in place, and the soft tissue of the wound was closed in layers without drainage. The limb was suspended in balanced traction in a hinged Thomas splint. The postoperative convalescence was somewhat stormy, but very satisfactory.

FIG. 4

Front and rear views of specimen removed at autopsy. The vitallium appliance is embedded in a large involucrum of bone.

A few days after the operation it was found that in moving this large muscular limb, the bone had fractured as expected. With this sequestrum of bone separated and lying within the appliance where it could not be nourished by normal blood supply,

there developed liquefaction necrosis, and a large amount of fluid accumulated in the deep tissues. It was feared that the entire area would break down with infection, and that the project would fail.

Six weeks following implantation of the appliance, another operation was performed. At this time the necrotic sequestrum of bone was removed. It was most interesting to observe that the soft tissues had adhered to the vitallium appliance so firmly that the periosteum had to be elevated in almost the same fashion that normal periosteum is stripped from normal bone. Following this observation, the authors were encouraged, and hoped that complete healing would take place, and that the appliance would be embedded in a normal bone involucrum. By means of skeletal traction the limb was held in suspension, and the lower fragment of the bone was kept in end-to-end apposition with the vitallium appliance. Healing progressed, and check-up roentgenograms revealed increasing bony union. Five months after the operation, union was solid, and the patient was allowed to be up and about on crutches, using a long thigh brace with pelvic band and large lacer cuff about the thigh to support the site of the fracture. Very soon, he was bearing full weight on the limb, and there was remarkable freedom from pain. There was voluntary active motion of the hip joint, of approximately 75 per cent. of normal. Within nine months following operation, he walked well without support, and only used a cane for long distances. One year following operation, he not only walked well, but picked up a grown man weighing two hundred and fifteen pounds, and walked about with him. Roentgenograms at this time showed a great mass of new-bone formation, extending from the intertrochanteric region of the femur at the capsular attachment downward, enveloping the vitallium appliance, and solidly uniting it to the lower femoral fragment. The patient continued to improve, and walked well without complaint. Moving pictures made fifteen months after operation reveal an excellent functional result.

Approximately a year and a half following operation, he began to show clinical evidence of cardiac decompensation. There was some swelling of both hands and feet. An acute cardiac attack developed and he was treated in the Hospital over a period of three weeks for cardiac failure. He returned to his home and was getting about well when, on June 2, 1942, while sitting on the side of his bed, he toppled forward and expired. Notice was received of his death, and consent for autopsy was obtained.

At autopsy, the entire femur and half of the pelvis were removed. A new hip joint with an almost normal appearing capsule and synovial lining were found. The bone specimen was preserved by boiling the bone in soapy water, and drying it in the sun. This specimen shows the extensive involucrum about the vitallium appliance. There was no evidence of recurrence of the giant-cell tumor. The vitallium appeared unaffected by its period of service in the body. It was just as bright and shiny as the day it was inserted and at no point on it was there any evidence of corrosion.

This patient was observed and treated over a period of approximately eight years. An ununited fracture, fifteen months' duration, of the femoral neck was cured by drilling and nailing with Moore nails. A giant-cell tumor was treated by roentgenotherapy, curettage, and massive bone graft. After six years, when tumor growth could no longer be controlled and pathological fracture had occurred, the upper one-half of the femur was resected and replaced successfully with vitallium.

OSTEOPATHIA CONDENSANS DISSEMINATA ASSOCIATED WITH COARCTATION OF THE AORTA *

A Case Report

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Osteopoikilosis, osteopetrosis, and melorheostosis are three types of condensing or sclerosing osteopathy which are generally believed to be congenital anomalies and hereditary in nature.

Melorheostosis was first described by Léri and Joanny in 1922. Roentgenographically, in this condition there is an irregular, condensed production of bone along the shafts of the bones in one extremity. These hyperostoses are deposited as strips of irregular thickness along the cortex of the long bones, giving the appearance of a viscous coagulating substance flowing slowly down a solid wall; this presents the so-called candle-flow appearance and is responsible for the choice of the term describing the disease—*melos* means "a member" and *rheo* means "to flow". Usually the normal contour of the bone is lost, but this is not always the case. Aldenhofen described a case involving the femur without any change of normal contour of the bone. Shortening of the leg and bowing or abnormal curvature of the bones characterize most of the adult cases.[7, 22] Paraesthesias, pain, and tenderness are frequent, and restriction of movement due to periarticular changes is seen in about 50 per cent. of the cases.[4] Occasionally progressive muscle weakness and scleroderma may be observed.[21] Kibby followed a case for seven years and did not notice any change or progression of the lesion.

Osteopetrosis, also called marble bones, Albers-Schönberg disease, osteosclerosis fragilis generalisata, or congenital osteosclerosis, is a disturbance of normal formation of bone characterized roentgenographically by a marked increase of the density of both the cortical and spongy portions of the entire skeletal system. Albers-Schönberg described the first case in 1904 and since then reports of 131 cases have appeared in the literature.[11] Symptoms secondary to the bone changes are sometimes seen, such as blindness, deafness, anaemia, splenomegaly, hepatomegaly, hydrocephalus, and pathological fractures.[6, 16] Microscopically there is seen only an increase in the number and thickness of the normal bone lamellae.[11] The chemical composition of the bone has been reported as being within normal limits[6, 11], but Kramer, Yuska, and Steiner found a high carbonate content in the case they examined. For the most part, the condition is a congenital or familial disease or anomaly

* Received for publication January 2, 1943.

of bone growth. Many patients go through life without symptoms developing.[8, 14, 20]

Contrary to the clinical picture of the two conditions just described, osteopoikilosis is usually asymptomatic, and is discovered during roentgenographic examination for some other lesion. In a case recently described by Baker and Jones, however, there was a disturbance of growth of one of the epiphyses about the knee as well as numerous contractures of tendons and deformity. Osteopoikilosis[24] is also called spotted bones, osteopecilia, and osteopathia condensans disseminata. This last term best describes the condition on an anatomicopathological basis; there is a "dissemination of areas of condensed bone elements".[19] This diffuse mottling may be limited to one bone or may be present in every bone of the body. Albers-Schönberg first described osteopoikilosis in 1915, and since then about seventy cases have been reported in the literature[10]. Nichols and Shiflett followed a case for seven years without observing any change in the lesions; but Holly, over a period of five years, did observe that some islands of condensation disappeared, others enlarged, and in some instances there was a fusion of two or more regions. Microscopically the regions of increased density are formed by numerous, thickened juxtaposed trabeculae which fade gradually into the normal spongy

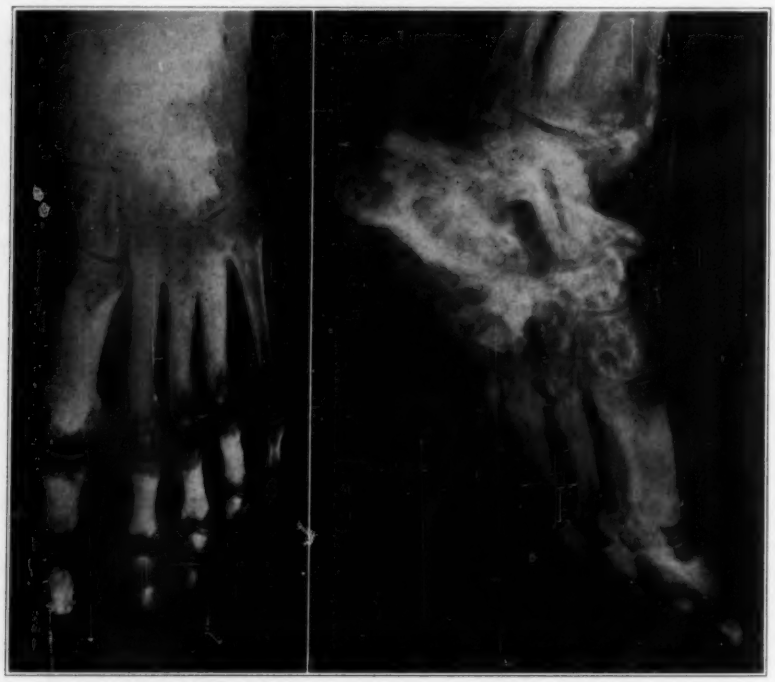

FIG. 1-A FIG. 1-B

Fig. 1-A: The shafts of the phalanges and metatarsal bones of the first four toes show increased density.

Fig. 1-B: Increased density is present in the regions of the tarsal bones and the lower end of tibia and fibula.

bone, and there are no sharply defined borders about the regions.[10, 12]

The authors have recently had the opportunity of examining at the Clinic a woman twenty-two years old who presents the picture of osteopoikilosis and, in addition, some of the characteristics of the other two types of sclerosing osteopathy—osteopetrosis and melorheostosis. This same patient also has coarctation of the aorta.

REPORT OF CASE

An unmarried white woman, aged twenty-two years, was seen in the emergency room at the Colonial Hospital on November 27, 1941. She stated that while at work as a maid in a home she stepped on a clothespin and twisted her left ankle. She immediately experienced considerable pain about the left ankle joint and came to the Hospital for treatment. Examination of the left ankle revealed some slight swelling and tenderness anterior to the external malleolus and just below and anterior to the internal malleolus; dorsiflexion of the foot aggravated the pain, although motion at the ankle joint was not limited. There was no clinical evidence of fracture. An adhesive strapping was applied to the ankle.

A roentgenogram of the left ankle and foot was taken the following day. This roentgenogram revealed an increased density of the shafts of all the phalanges and metatarsals except those of the fifth toe (Fig. 1-A), and scattered regions of increased density involving all the other bones of the foot and the lower end of the tibia and fibula (Fig. 1-B). There was also noted a large exostosis on the dorsal surface of the tarsus overlying the astragaloscaphoid joint (Fig. 1-B).

The patient was much surprised to learn that she had this peculiar condition in her bones. A more detailed history was obtained and a complete physical examination was performed. Roentgenograms were taken of the skull and of all the long bones, and laboratory studies were made.

The patient stated

FIG. 2

Showing notching of the ribs, diagnostic of coarctation of the aorta, and also disseminated regions of sclerosis of the scapula and humerus.

that she had always been in good health. She sustained a slight injury to the left ankle nine years ago, but this condition subsided without any residual soreness or stiffness. A heart murmur was detected by the school physician, and swimming at school was forbidden on this account. During the past two or three years she had noticed a rapid pulse and palpitation.

The father and mother of the patient were living and well. The mother had had chorea at thirteen years of age. Three siblings were living and well.

Physical examination revealed the typical findings of coarctation of the aorta. The heart was not enlarged. There was a loud systolic murmur heard best at the base and transmitted laterally along the clavicles. There were tortuous pulsating intercostal and posterior scapular arteries. No pulsations could be felt in the abdominal aorta, and the femoral pulsations were barely palpable. Blood pressure in the arms was 216 millimeters of mercury systolic, with a diastolic bruit heard to zero; blood pressure in the legs was 110/0.

Results of urinalysis and of the flocculation test for syphilis were negative. The content of hemoglobin was 14.8 grams per 100 cubic centimeters of blood; leukocytes numbered 8,500 and erythrocytes 4,370,000 in each cubic millimeter of blood; the sedimentation rate was seven millimeters in one hour. Samples of blood were drawn on three occasions and examined for the content of calcium, phosphorus, and phosphatase; an average of these three showed:

Calcium — 10.2 milligrams per 100 cubic centimeters of blood,

Phosphorus — 3.1 milligrams per 100 cubic centimeters of blood,

Phosphatase — 1.6 Bodansky units.

Roentgenograms of the skull were reported negative. Roentgenograms of the chest showed a notching of the ribs diagnostic of coarctation of the aorta (Fig. 2). Of

FIG. 3

Scattered regions of sclerosis are visible in the left innominate bone and the left femur.

all the other bones, the left innominate, left femur, left tibia, left fibula, all the bones of the left foot, the right scapula, right humerus, and right carpal bones were revealed as the sites of disseminated regions of bone sclerosis (Figs. 2, 3, 4-A, 4-B, and 5). There was discrete mottling throughout the bones in the carpus and tarsus and in the region of the epiphyses and metaphyses of the left femur, tibia, and fibula, and the right humerus. The coracoid process, the neck and the body of the scapula, and the entire left innominate bone revealed similar spotting together with a more diffuse sclerosing process. The diaphyses of the left femur, tibia, and fibula, however, showed a remarkable generalized sclerosis with marked thickening of the cortices.

The patient was last seen on March 7, 1942. At this time she made no more complaints referable to the sprained left ankle, but she still complained of palpitation and nervousness.

This case presents the disseminated spherical and elongated regions of increased density in the bones which characterize osteopoikilosis. Linear striae, — that is, streaks of condensation along the shaft of the bones, have also been described in osteopathia condensans disseminata [3, 12, 25, 26]; and these lesions were also seen in this case. The remarkable thickening of the cortices of the right femur and tibia, however, is more characteristic of melorheostosis or of osteopetrosis. The extreme density of the

FIG. 4-A FIG. 4-B

Fig. 4-A: There are scattered regions of sclerosis in the distal end of the right humerus.

Fig. 4-B: Discrete mottling can be seen throughout the right carpal bones.

diaphyses of the phalanges also gives the appearance, not of osteopoikilosis, but rather of osteopetrosis. To the authors' knowledge, no case exactly comparable to this one has been described in the literature. They feel, however, that osteopathia condensans disseminata is a sufficiently descriptive term to enable them to classify the case as one of this condition.

Much has been written concerning the possible causation of these three diseases. Endocrines, vitamins, infections, toxins, and so forth, have been blamed, but all authors admit the strong possibility of the existence of a congenital anlage. The possibility that diminished blood supply to the bones may play a rôle in the production of these conditions has not been studied thoroughly. Greig stated, "vasodilator changes . . . precede and accompany the rarefying stage of all osteodystrophies", and "diseases characterized by restriction of the circulation (and typical of this may be cited endarteritis obliterans syphilitica), are accompanied by osteosclerosis and increased density of the bone". When the blood supply to a bone is diminished, sclerosis supervenes; and when the blood supply is obliterated completely, there is necrosis of bone. Calcification occurs only in feebly vascularized structures; it is not a primary manifestation, but is rather a secondary evidence of

FIG. 5

Generalized sclerosis and marked cortical thickening of the diaphyses of the left tibia and fibula are visible, together with discrete mottling in the region of the metaphyses.

some functional deterioration of the structure in which it occurs[25]. Cave explained the sclerosing effect of the osteoplastic metastatic growths of prostatic carcinoma on the basis of a constant local stimulation of the sympathetic ganglia by the carcinomatous lymph nodes in the lumbar and pelvic regions, producing vasoconstriction of the nutrient arteries of the pelvic bones. He stated that when osteoclastic metastatic growths are irradiated, their blood supply is diminished, and the cancer cells are then able to absorb calcium in large amounts.

One must certainly admit that a diminution of blood supply produces sclerosis of bone; that is, it promotes an increased deposition of calcium salts, but whether such a diminution of nutrition will also produce the discrete regions of bone sclerosis seen in osteopoikilosis or melorheostosis is somewhat doubtful. Hinson suggested that osteopoikilosis may be due to a congenital anomaly of the terminal arteries activated by some glandular dyscrasia, producing "acromegaly" of discrete islands of bone. In this case, one can scarcely assume on the basis of the coarctation of the aorta alone that the blood supply of the left leg is less than that of the right; yet all bones of the right leg are free from any sclerosing lesions.

The authors shall have to agree with other authors that all of these sclerosing osteopathies are probably due to some defect of genetic arrangement with some faulty differentiation and growth of bone from mesenchyme [11, 26].

In conclusion, a case of osteopathia condensans disseminata has been presented which has some of the characteristics of three types of sclerosing osteopathy—osteopoikilosis, osteopetrosis, and melorheostosis—and in which the patient also has an associated coarctation of the aorta.

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ROBERT LIDE CARROLL

1895–1943

With the passing of Dr. Robert Lide Carroll, not only Los Angeles but a much wider area has lost an outstanding surgeon and a true gentleman.

Dr. Carroll grew up in Columbia, South Carolina, and after attending college there, went to the University of Pennsylvania where he was graduated in 1926. He was a member of Phi Chi fraternity. In 1930 he returned to his home city to marry Jean Wilson. They had two children, Robert, Jr., now aged twelve, and Jean, aged nine.

Fourteen years ago, Dr. Carroll went to Los Angeles from Cleveland, where he had been under Dr. James Dickson at the Cleveland Clinic, to take postgraduate work with special emphasis on the non-operative aspects of this specialty. He continued work at the Orthopaedic Hospital in Los Angeles on a fellowship, and during the next two years made a survey and study of 356 cases of scoliosis. Through his interest and influence, the Orthopaedic Hospital began to use the turnbuckle-jacket to obtain correction, and this greatly improved results and lessened the period of hospitalization.

Because of his great interest and ability, he was made Assistant Director of the Department of Educational Activities, conducted by the Crippled Children's Guild, and in 1935 was put in charge of the Department of Survey and Fact Finding, also acting on the Educational Committee. His interest and teaching ability led to his appointment as Instructor in the Physical Education Department of the University of Southern California; he lectured on corrective physical education to the seniors. His loss will be great in this field which interests very few orthopaedic surgeons, and in which he made a vital contribution to health education.

Dr. Carroll recently completed a follow-up survey of poliomyelitis cases, which was conducted under a grant from The National Foundation for Infantile Paralysis. He studied 1,767 cases, and personally re-examined 850 patients. In this study he showed his integrity, his unswerving scientific attitude, and his keen sense of responsibility.

He died on June 7, at the age of forty-eight, at the height of his usefulness, and his loss is great to hundreds of crippled children and adults. These he served as Orthopaedic Consultant at the County Hospital, Arlington, California, as Chief of the Orthopaedic Service at the California Hospital, Los Angeles, and as a member of the Professional Advisory Committee of the Crippled Children Services for the State of California, as well as in the Orthopaedic Hospital.

The respect of his orthopaedic colleagues has been well shown by his election to offices in the Los Angeles Orthopaedic Society, and the Western Orthopaedic Association, of which he was the secretary. His associates in these societies will miss his sincere yet dynamic personality, and his very responsible conduct of their affairs. He was an active member of The American Academy of Orthopaedic Surgery, and was an applicant for membership in The American Orthopaedic Association.

MURRAY SNELL DANFORTH

1879–1943

Dr. Murray Snell Danforth passed away on the eve of the Fifty-Seventh Annual Meeting of The American Orthopaedic Association,—the Meeting at which he was to report on his brief stewardship as Editor of *The Journal of Bone and Joint Surgery*. Dr. Danforth had served for several years as Vice-Chairman of the Board of Associate Editors of *The Journal*. Following the untimely death of Dr. Brackett, he had agreed to assume the duties of this important office until a successor could be appointed. It was destined that he should perform this task for but a few brief months.

Dr. Danforth was born May 16, 1879, at La Grange, Maine, and was educated in the public schools of Bangor. He received the degree of A.B. from Bowdoin College in

1901 and was elected to Phi Beta Kappa. In 1941 his Alma Mater awarded him the honorary degree of Sc.D. He was graduated from Johns Hopkins University in 1905 with the degree of M.D., and a year later began a two-year internship at the Rhode Island Hospital. At the end of this service Dr. Danforth settled in Providence, and for a few years engaged in general practice. He had been persuaded by medical advisors to take up the practice of orthopaedic surgery, and began work in the Orthopaedic Department of the Rhode Island Hospital, at the same time carrying on postgraduate study at the Massachusetts General Hospital.

In 1913 he was appointed Orthopaedic Surgeon to the Rhode Island Hospital, and immediately set out for England to study with Sir Robert Jones and at other orthopaedic clinics in Europe. On return to this country he resumed orthopaedic practice until the outbreak of World War I. Dr. Danforth was one of the group of twenty orthopaedic surgeons who volunteered for service under Sir Robert Jones in the British Orthopaedic Hospitals, and was stationed at Bangour, near Edinburgh, for nearly two years. He enlisted as a Captain in the Medical Corps of the United States Army, and before the end of this service was promoted to the rank of Major. On his retirement to private life he was given the rank of Lieutenant Colonel. While at Bangour, he became greatly interested in peripheral-nerve surgery and tendon transplantation. After the Armistice he was transferred to Savenay, France, where he was assigned to the Embarkation Service. Early in 1919 he returned to this country, and served until October of that year as Chief of the Orthopaedic Service at Walter Reed Hospital in the rehabilitation of wounded soldiers.

Dr. Danforth was consulting orthopaedic surgeon to Butler Hospital and Charles V. Chapin Hospital, Providence; and consulting surgeon to South County Hospital, Westerly Hospital, and Wallum Lake Sanatorium. He was Chief of the Fracture Service at the Rhode Island Hospital from its inception in 1931 until his death. Dr. Danforth was a Diplomate of the American Board of Orthopaedic Surgery, and a member of The American Orthopaedic Association, The American Academy of Orthopaedic Surgeons, the Boston Orthopaedic Club, and the Interurban Orthopaedic Club. He served as President of the Providence Medical Association in 1941, and on June 2, 1943, was inducted as President of the Rhode Island Medical Society. In assuming this office, Dr. Danforth demonstrated a remarkable degree of courage, in view of his recent illness; on the following day he was fatally stricken and died June 5, 1943.

He was a Trustee of the Rhode Island Foundation for Infantile Paralysis, and a member of the Crippled Children's Division of the Rhode Island Department of Public Health. The Murray S. Danforth Fund, established by his family connections, was a substantial contribution to the care and treatment of crippled children at the Crawford Allen Memorial,—the country branch of the Rhode Island Hospital.

His major publications include "The Anatomy of the Lumbo-Sacral Region in Relation to Sciatic Pain", a research carried on conjointly with Dr. Philip D. Wilson; and "The Treatment of Legg-Calvé-Perthes Disease without Weight-Bearing", derived from his experience with these cases at the Wallum Lake Sanatorium.

During his early years of Out-Patient work he was confronted with the large number of patients of Italian origin who were unable to speak English. This circumstance caused him to study Italian so that he became proficient in reading as well as speaking the language. This talent was of much benefit to the entire clinic as well as a cause of considerable personal satisfaction. He was a stickler for the use of correct English, and spared no pains to employ the accurate word. Dr. Danforth found much happiness in growing roses on his farm in Exeter, Rhode Island, where he spent much of his leisure time. Perhaps his most satisfying interest was found in European travel. Whenever possible he made a journey each year, and never failed to visit Scotland, where he had made some firm friends.

Although quiet and retiring by nature, he was loyal in his friendships, and was always tolerant of the opinions of others. He was highly regarded as a consultant, and worked unceasingly for the improvement of orthopaedic treatment in his community.

News Notes

At the meeting of the Executive Committee of **The American Orthopaedic Association,** held in Cleveland on Monday, June 7, 1943, in connection with the Annual Meeting, Dr. Charles F. Painter, of Boston, Massachusetts, was appointed Editor *pro tempore* of *The Journal.*

The **Association of Military Surgeons of the United States** will hold its Fifty-First Annual Convention in Philadelphia at the Bellevue-Stratford Hotel, October 21 to 23, 1943, inclusive, according to an announcement by association officers.

The three-day convention will assemble doctors from all the current war fronts where United States forces are fighting, and from the great base hospitals where rehabilitation of the wounded is in progress. They will bring with them information on the latest techniques of wartime medicine and surgery. Numerous forum lectures, practical demonstrations, moving pictures, and teaching panels are planned to present the wealth of data to the convention.

Honorary Chairman of the Convention this year is Rear Admiral Ross T. McIntire, Surgeon General of the Navy. The General Chairman is Captain Joseph A. Biello, Medical Corps, United States Navy, who is District Medical Officer of the Fourth Naval District.

THE AMERICAN ORTHOPAEDIC ASSOCIATION

The Fifty-Seventh Annual Meeting of The American Orthopaedic Association—Dr. Frank R. Ober, President—was held at the Hotel Cleveland, Cleveland, Ohio, on June 7 and 8, 1943. On account of the War, there was no clinical day, and many of the social features of previous years were omitted. The scientific parts of the program were of great interest, and the standard of the papers, from both guests and members, was exceptionally good. Considering the short time that the Program Committee had in which to prepare for the Meeting, because of the uncertainty as to whether there would be a Session in 1943, they cannot be too highly commended for their efforts.

Monday, June 7

Morning Session

Delayed Reduction of Fractures.
Dr. John Royal Moore, Philadelphia, Pennsylvania.
Discussion: Dr. M. N. Smith-Petersen, Boston, Massachusetts.
Dr. George E. Bennett, Baltimore, Maryland.
Dr. Edwin W. Ryerson, Chicago, Illinois.
Dr. J. Albert Key, St. Louis, Missouri.

Peripheral-Nerve Pathology Associated with Congenital Deformities.
Dr. Beveridge H. Moore, Chicago, Illinois.
Discussion: Dr. A. Bruce Gill, Philadelphia, Pennsylvania.
Dr. J. Albert Key, St. Louis, Missouri.
Dr. Edwin W. Ryerson, Chicago, Illinois.

Experiences with the Kenny Treatment for Acute Poliomyelitis in the Epidemic of 1942, Monmouth and Ocean Counties, New Jersey.
Dr. Nicholas S. Ransohoff, New York, N. Y.

The Significance of the Iliocostal Fascial Graft in Paralytic Deformities of the Trunk.
Dr. Leo Mayer, New York, N. Y.

Analysis of Neuromuscular Disorders in Poliomyelitis.
Dr. Joseph Moldover, Brooklyn, New York. (By invitation.)
Discussion: Dr. Alan DeF. Smith, New York, N. Y.
Dr. Leo Mayer, New York, N. Y.
Dr. Joseph A. Freiberg, Cincinnati, Ohio.
Dr. Nicholas S. Ransohoff, New York, N. Y.
Dr. Steele F. Stewart, Los Angeles, California.
Anterior Capsuloplasty of the Elbow for the Relief of Flexion Contractures following Fractures of the Lower End of the Humerus.
Dr. Philip D. Wilson, New York, N. Y.
Discussion: Dr. Leo Mayer, New York, N. Y.

Afternoon Session

President's Address.
Dr. Frank R. Ober, Boston, Massachusetts.
Some Lipoid Disorders Involving Bones.
Dr. Sidney Farber, Boston, Massachusetts. (By invitation.)
Results of Fifty Cases of the Use of the Clothespin Graft for Spondylolisthesis, Laminal Defects or Disc Defects of the Lumbar Spine.
Dr. David M. Bosworth, New York, N. Y.
Herniated Intervertebral Disc.
Dr. J. Jay Keegan, Omaha, Nebraska. (By invitation.)
Discussion: Dr. David M. Bosworth, New York, N. Y.
Dr. Edwin W. Ryerson, Chicago, Illinois.
Dr. Philip D. Wilson, New York, N. Y.
Dr. Samuel Kleinberg, New York, N. Y.
Subastragalar Arthrodesis in Fractures of the Os Calcis.
Dr. W. E. Gallie, Toronto, Ontario, Canada.
Discussion: Dr. E. Bishop Mumford, Indianapolis, Indiana.
Dr. Robert D. Schrock, Omaha, Nebraska.
Dr. Alan DeF. Smith, New York, N. Y.
Dr. J. Jay Keegan, Omaha, Nebraska.
Dr. Arthur Steindler, Iowa City, Iowa.

TUESDAY, JUNE 8

Morning Session

Local Shock and Block of Sympathetics on Circulatory Phenomena in an Injured Extremity.
Dr. J. E. M. Thomson, Lincoln, Nebraska.
Shock in Extremity Surgery.
Dr. Dallas B. Phemister, Chicago, Illinois.
The discussion of the preceding two papers was by:
Dr. John Fulton, New Haven, Connecticut.
General Norman T. Kirk, Washington, D. C.
Dr. Steele F. Stewart, Los Angeles, California.
Dr. W. E. Gallie, Toronto, Ontario, Canada.
Chronic Bone Infection and Sulfonamides.
Dr. J. Albert Key, St. Louis, Missouri.
Discussion: Dr. H. Winnett Orr, Lincoln, Nebraska.
Dr. Frank D. Dickson, Kansas City, Missouri.
The Exposure and Repair of Shoulder-Cuff Lesions.
Dr. Harrison L. McLaughlin, New York, N. Y. (By invitation.)

Discussion: Dr. M. N. Smith-Petersen, Boston, Massachusetts.
Dr. David M. Bosworth, New York, N. Y.
Dr. Philip D. Wilson, New York, N. Y.
Dr. J. Albert Key, St. Louis, Missouri.
Dr. Samuel Kleinberg, New York, N. Y.

Certain Aspects of the Anatomy of the Shoulder and Some New Concepts about the Functional Anatomy about the Shoulder Joint.
Dr. LeRoy C. Abbott, San Francisco, California.
Dr. John B. deC. M. Saunders, San Francisco, California. (By invitation.)
Dr. Verne T. Inman, San Francisco, California. (By invitation.)

Afternoon Session

Solitary Bone Cyst.
Dr. Samuel Kleinberg, New York, N. Y.
Discussion: Dr. George E. Bennett, Baltimore, Maryland.
Dr. Frank R. Ober, Boston, Massachusetts.
Dr. J. Albert Key, St. Louis, Missouri.
Dr. W. E. Gallie, Toronto, Ontario, Canada.

Preparation of Specimens for Orthopaedic Teaching.
Dr. John B. deC. M. Saunders, San Francisco, California. (By invitation.)

Aerial Transportation of the Sick and Wounded.
Dr. John Fulton, New Haven, Connecticut. (By invitation.)

The Use of Aluminum Acetate in the Treatment of Osteitis Fibrosa, Paget's Disease, and Osteoporosis.
Dr. Ralph K. Ghormley, Rochester, Minnesota.
Dr. John J. Hinchey, Rochester, Minnesota. (By invitation.)
Discussion: Dr. Joseph A. Freiberg, Cincinnati, Ohio.
Dr. A. Bruce Gill, Philadelphia, Pennsylvania.

Relationship of Legg-Perthes Disease to the Function of the Thyroid Gland.
Dr. A. Bruce Gill, Philadelphia, Pennsylvania.
Discussion: Dr. J. Albert Key, St. Louis, Missouri.

Two Executive Sessions were held at noon on June 7 and 8, respectively. The Annual Association Dinner was given on Monday evening, the first day of the Meeting.

Dr. A. Bruce Gill, Philadelphia, Pennsylvania, is President of The Association for the year 1943–1944.

At the Executive Session, the following new officers and members of committees were elected:

Officers

President-Elect: Dr. J. Albert Key, St. Louis, Missouri.
Vice-President: Dr. Samuel Kleinberg, New York, N. Y.
Secretary: Dr. Charles W. Peabody, Detroit, Michigan.
Treasurer: Dr. Frank D. Dickson, Kansas City, Missouri.

Committee members and delegates

Membership Committee: Dr. Guy W. Leadbetter, Washington, D. C.
Program Committee: Dr. Henry R. McCarroll, St. Louis, Missouri.
Research Committee: Three men were elected for one, two, and three years, respectively, as this is an elective committee for the first time.
Dr. Paul C. Colonna, Philadelphia, Pennsylvania,—one year.
Dr. Joseph A. Freiberg, Cincinnati, Ohio,—two years.
Dr. Russell P. Schwartz, Rochester, New York,—three years.

Representatives on the American Board of Orthopaedic Surgery:
Dr. Fremont P. Chandler, Chicago, Illinois.
Dr. G. E. Haggart, Boston, Massachusetts.
Delegate to the American College of Surgeons: As no meeting of the College was held in 1942, the delegate remains unchanged,—Dr. E. W. Ryerson, Chicago, Illinois.

At this Meeting, the following were received into membership:

Active members

Dr. Harry C. Blair, Portland, Oregon.
Colonel O. B. Bolibaugh, U. S. Army (Overseas).
Dr. George K. Coonse, Boston, Massachusetts.
Dr. Sylvan L. Haas, San Francisco, California.
Dr. M. Beckett Howorth, New York, N. Y.
Dr. Donald E. King, San Francisco, California.
Dr. A. D. LaFerté, Detroit, Michigan.
Dr. Paul B. Magnuson, Chicago, Illinois.
Dr. D. Murray Meekison, Vancouver, British Columbia, Canada.
Dr. C. L. Mitchell, Detroit, Michigan.
Dr. L. C. Wagner, New York, N. Y.

ACKNOWLEDGMENTS

The Journal wishes to acknowledge the receipt of the following publications sent to the Editorial Department:

Anais Paulistas de Medicina e Cirurgia (São Paulo, Brasil), XLIV, Nos. 4, 5, 1942; XLV, No. 2, 1943.

Boletim do Sanatório São Lucas (São Paulo, Brasil), IV, Nos. 4, 5, 1942; IV, No. 8, 1943.

Boletin del Colegio Médico de la Habana (Cuba), VI, Nos. 3, 4, 5, 1943.

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Current Literature

OPERATIVE ORAL SURGERY. Leo Winter, D.D.S., M.D., F.A.C.D., F.A.C.S. Ed. 2. St. Louis, The C. V. Mosby Co., 1943. $12.50.

This is the second edition of Winter's "Operative Oral Surgery". There have been added brief chapters on chemotherapy, shock, burns, war wounds, dislocation and subluxation of the temporomandibular joint articulation, and pin fixation or skeletal fixation for the treatment of fractures. The chapter on general anaesthesia has been enlarged and that on oral manifestations of blood dyscrasias has been revised and rewritten. The numerous illustrations, both old and new, occupy fully half the pages of this large book and are a most valuable part.

The author emphasizes four subjects,—exodontia, cysts of the jaws, fractures, particularly of the mandible, and osteomyelitis of the mandible. The rest of the material in the book is not covered in the same detail although there are, in these chapters, many interesting illustrations and roentgenograms.

In the consideration of fractures of the mandible, the usefulness of the Winter arch wire is stressed. There are several series of drawings illustrating the application of various types of fixation including interdental wiring, interdental elastics with the Winter splint, circumferential wiring of the edentulous jaw with fixation by an intra-oral vulcanite splint, and extra-oral traction on the displaced posterior fragment. In fractures at the angle with a molar tooth in the fracture line, useful for preventing the elevation of the posterior fragment, the author has been willing to leave the tooth in place. It is removed only if there is evidence of infection or when sufficient union has occurred to make removal permissible. There are several roentgenograms, however, showing osteomyelitis developing about the teeth left in a fracture line. Immediate external drainage of the fracture is not discussed.

In the chapter on osteomyelitis, the author wisely stresses the importance of conservatism in treatment by maintaining adequate drainage and waiting for sequestration. It is unfortunate with the increasing use of chemotherapy in his cases that he does not record cultures of pus as a check on the effectiveness of the therapy. The series of photographs of a surgeon, who is draining an abscess of the jaw with his bare hand, is a distressing sight.

This book is an encyclopedic text covering the field of oral surgery. The emphasis is on those phases of the subject most interesting to the dental surgeon. It is extremely well illustrated with roentgenograms, photographs, and drawings.

LESIONES TRAUMATICAS DEL ASTRAGALO (Traumatic Lesions of the Astragalus). Dr. José Manuel Del Sel. Buenos Aires, Aniceto Lopez.

The astragalus is a very important bone, since it supports the entire body weight, and its permanent disturbance may result in great permanent disability. The purpose of this profusely illustrated monograph of 135 pages is to present the correct method of treatment and the prognosis of the lesions according to the pathological anatomy. The author divides traumatic lesions of the astragalus into two main groups,—dislocations and fractures. With dislocations, there is often an accompanying fracture of one of the nearby bones, particularly the tibia or fibula. Since the astragalus has no muscle attachments, it is relatively free, and dislocation after a fracture of one of the malleoli is not so difficult. This constitutes a fracture-dislocation. Fracture-dislocation of the astragalus itself is not rare in the presence of violent trauma.

Dislocations are divided into several types: enucleation of the astragalus, often referred to as a double or total lesion, in which the bone is completely displaced from its normal position; tibiotarsal dislocation, in which the ankle joint is dislocated; and two kinds of subastragalar dislocation,—in one of which the foot is displaced forward and

inward, and in the other, the foot is displaced outward. The mechanism of injury in each type is discussed in detail.

In general, fractures of the astragalus are classified by region, as head, neck, body, and apophysis. There are also fractures of the smaller processes, which may be sagittal, comminuted, or simply cracks. Each of these types is discussed in detail, including, symptoms, roentgenograms, and case histories with emphasis laid on the importance of good, early roentgenograms. Special views which are sometimes indicated are described. The so-called indirect violence is the most usual mechanism involved in the production of the various fractures.

The circulation of the astragalus is beautifully illustrated with photographs of injected specimens prepared by Suárez under the direction of Prof. Fracassi.

A great deal of space is devoted to details of treatment, with exact descriptions of the techniques of closed manipulation and of open reduction for the various types of fractures.

Among the complications of these conditions are aseptic necrosis and traumatic arthritis. The importance of aseptic necrosis of the astragalus cannot be overemphasized, although, in some cases, the bone will regain its vitality after prolonged immobilization and rest. Traumatic arthritis is a relatively common occurrence, the subastragalar joint being the most commonly involved. Ankylosis often gives the best result. The prognosis in astragalar fractures in general is discussed.

The book is beautifully prepared, written, and illustrated. The roentgenographic reproductions are of good quality. A series of thirty-three cases is presented in detail, with an analysis of results. A large bibliography is given which is interesting because it contains South American, French, Italian, and German references with only a few American or English ones. The reviewer was impressed with the high quality of the monograph in general.

THE METABOLIC COST OF MAINTAINING A STANDING POSITION. WITH SPECIAL REFERENCE TO BODY ALIGNMENT. Harriet G. McCormick. New York, King's Crown Press, 1942. (Lithographed) $1.25.

In this thesis the author attempts to determine whether there is a relationship between the way an individual stands and the amount of energy he uses in maintaining that position. Only accustomed positions were assumed. The metabolic cost of this standing position was determined by taking the basal metabolic rate as a base line and the metabolic cost of the standing position was found by taking the difference between the basal and standing metabolic rates. It was then determined whether there was any relationship between the increase in the metabolic rate in standing and the score on a given posture test. Since what is considered good and poor posture is somewhat controversial, only objective measurements were used following the test of MacEwan and Home. Investigations were carried out on healthy young adult women. Data were obtained on fifty subjects. Standard technique was used in measuring the metabolic rate. The author concluded from this study that for the normal healthy individual of average height and weight there was very little difference in the expenditure of energy in varying body alignment in standing. It was found that the measurements of body alignment accounted for only 33 per cent. of the slight variance in the metabolic increase.

ORTHOPEDIC CONDITIONS AT BIRTH. NURSING RESPONSIBILITIES. Jessie L. Stevenson, R.N. Published (Lithographed) and Distributed by the Joint Orthopedic Nursing Advisory Service of the National Organization for Public Health Nursing and the National League of Nursing Education. New York, 1943.

This paper-covered booklet of eighty pages is designed for the nurse who has not had orthopaedic training, and purposes to assist her in early recognition of the conditions discussed, gives time-proved directions for nursing care, and makes suggestions for

instruction of the family in the care of the baby and adjustment to the situation. The contents include Brachial Birth Palsy, Cerebral Palsy, Congenital Deformities of the Foot, Congenital Dislocation of the Hip, Torticollis, and Spina Bifida. Cerebral palsy is covered most completely and is well done. Had the anatomy of the other conditions been as thoroughly covered, the text would have gained in value and made a wider appeal. The bibliography at the end of each chapter lists well-known authorities. This book should prove helpful to the group for whom it was written.

THE MARCH OF MEDICINE. THE NEW YORK ACADEMY OF MEDICINE LECTURES TO THE LAITY, 1942. New York, Columbia University Press, 1943. $2.50.

This small volume, the seventh in the series of The New York Academy lectures for the laity, presents in understandable form much information of great interest and value to those who take seriously the social problems which the age in which we live presents.

These lectures have been prepared by authoritative writers, specialists in their line, and they have sought to throw light on subjects about which the public should be intelligently cognizant. These are not questions of mere academic interest. Certain of them have a very vital bearing upon the problems of our civilization, and the more widely information on these matters can be disseminated, the more intelligent will be the cooperation of the citizenry. For this reason, The Academy is to be commended for these admirable lecture courses.

THE NEUROMUSCULAR MATURATION OF THE HUMAN INFANT. Myrtle B. McGraw. New York, Columbia University Press, 1943. $2.00.

This book is a summary of studies on the neuromuscular development of the infant and child, which were carried on over a period of many years. The results of some of the studies have been published previously in various journals. After a discussion of the relationship of the anatomical and functional development of the infant, a general description of neonatal behavior is given. The development of neuromotor activities is studied and analyzed in great detail. The Moro reflex, the newborn infant's response to a startling stimulus, was studied by moving pictures. By counting the number of the sixteen millimeter frames exposed in photographing each response, numerical values of the duration of each phase of the reaction could be obtained. The average duration of the reflex for the different ages is represented in a curve, which has its peak at about one month, and declines rapidly after three months. Suspension-grasp behavior was also studied quantitatively by determination of the time of the duration of the suspension. The trend of development is shown in a curve which indicates that the intensity of the response tends to increase during the first thirty days, after which a gradual decline sets in. Swimming, postural adjustment, rolling from supine to prone position, crawling and creeping, development of a sitting and of an erect posture etc., were studied and analyzed carefully for the different age groups. A chapter on early sensory development is added. Individual development of behavior, as studied by Campbell and Weech, is also discussed. Observations on forty children, including five sets of unisexual twins, were analyzed in order to determine "whether or not they contain criteria which are capable of characterizing the individual child against a background of his peers". It was found that the individual child can be identified, but not accurately identified, by the state of his development at the time of birth. Individuality is better expressed by the velocity of change with advancing age. The most significant indications of individuality were yielded by the criteria which described achievement at progressive age periods. A chapter on maturation and learning concludes the book. To physicians interested in quantitative measurements of the functional maturation of infants, this book will be stimulating and valuable.

OUTLINE OF ROENTGEN DIAGNOSIS. AN ORIENTATION IN THE BASIC PRINCIPLES OF DIAGNOSIS BY THE ROENTGEN METHOD. Leo G. Rigler, B.S., M.B., M.D. Ed. 2. Atlas Edition. Philadelphia, J. B. Lippincott Company, 1943. $6.50.

The second edition of Dr. Rigler's book contains some valuable additions. The book is intended as an outline to be used both by teachers of radiology and by undergraduate students. Although it does not reach the standards set many years ago, in the more concise monograph by Holmes and Ruggles, it may be used to advantage by the steadily increasing number of students and graduates whose work depends upon roentgenographic aid. Dr. Rigler's reputation as an outstanding radiologist is firmly established, and his book bears witness to his experience and knowledge. Some errors, redundancies, and ambiguities of presentation will doubtless be eliminated in a subsequent edition. The chapters dealing with bone diseases and arthritis need rewriting. The drawings are informative, and the legends instructive. Students and teachers will find this book useful.

FRACTURES AND FRACTURE TREATMENT IN PRACTICE. Kurt Colsen, M.D. Johannesburg, South Africa, Witwatersrand University Press, 1942. 12 shillings, 6 pence.

This 143 page manual, evidently compiled for students at this South African University Medical School is recommended to the students by the Professor of Surgery of the University, I. W. Brebner. The author has presented good, brief, word pictures of the common fractures.

The illustrations are line drawings.

It is interesting that the author follows in his compilation Lorenz Böhler of Vienna and R. Watson-Jones of England. While the book is very condensed, it is in general well done. A student in the medical school would not go far wrong in treating a fracture, if he follows the suggestions in this manual.

Definite methods of treatment are described and there is no discussion of differences in treatment.

MILITARY SURGICAL MANUALS VOLUME IV. ORTHOPEDIC SUBJECTS. Prepared and Edited by the Subcommittee on Orthopedic Surgery of the Committee on Surgery of the Division of Medical Sciences of the National Research Council. Philadelphia, W. B. Saunders Company, 1942. $3.00.

This small volume has much valuable information in it but contains very little data which is going to be helpful to the civilian physician, who, because of the exigencies of war, has to meet the problems encountered in the field, the station hospital, or the general hospital. Rather, it is a book suited for the house surgeon on a graduate orthopaedic service, where the personal ideas expressed by the various authors can be subjected to the contemplative criticism of men of experience.

The first section on "Non-union", while recording methods which undoubtedly work in the skilled hands of the author, will lead men, well trained in surgery, but inexperienced in bone surgery, into many catastrophes. Casual descriptions of complicated operations about the hip, and massive bone-substitution operations, have no place in a volume of this type. The general advocacy of non-padded plaster without mention of the dangerous circulatory complications arising from its unskilled use detracts from the value of this book. The many pages devoted to complicated operations for the cure of ununited fractures could well be replaced by a clear exposition of the causes which lead to non-union and an emphasis in detail of the errors in clinical management of acute fractures, which make later bone-grafting operations necessary.

The second section on "Injuries of Spinal Column" is excellently written and the principles of treatment outlined eminently sound. The section might serve its purpose in this book better if some pages had been devoted to the improvisation of apparatus for carrying out treatment rather than showing ingenious tables which may not be available

to the doctor in military or naval service. More emphasis could also be placed on the ease with which compression fractures of the spine are sustained and necessity for complete roentgenographic examination in all trauma to the spine.

Section three covering "Compound Fractures" enunciates sound surgical principles, summarizes various methods of treatment well, and when personal choices are stated clearly, labels them as such.

The difference between civilian practice and military practice in handling wounds and compound fractures is clearly stated, and reasons are given why certain methods reasonably safe in civilian life are extremely hazardous in military practice, particularly the closure of wounds. In spite of this, a little too much enthusiasm about closure of wounds when combined with the use of the sulfonamides pervades this chapter.

Section four covering "Hematogenous Osteomyelitis" does so in masterful fashion. The military surgeon however is not going to be treating children. If, instead of devoting 100 pages to a disease of childhood and five pages to the exogenous osteomyelitis which is a sequela of compound fractures, and high-explosive and bullet wounds, the content had been reversed, this chapter would be more helpful to the general surgeon who is confronted with this problem. Again the intoxicating influence of the sulfonamides is evident, when the author advocates the operative procedure for immediate closure after operation of osteomyelitic areas, which has not yet had the test of time nor the approval of many surgeons experienced in this problem.

In summary it appears to the reviewer that this volume misses its point as stated in the Foreword. Much of its contents should be deleted and treatises on such commonplace subjects as disabilities of the feet, injuries and derangements of the knee joint, fractures of the carpus and wrist, injuries about the shoulder, and back sprains should be substituted. The average physician untrained in orthopaedic surgery is going to be faced with these problems much more frequently than he is with the necessity for reconstructing a hip or doing a massive bone graft.

YOUR ARTHRITIS. WHAT YOU CAN DO ABOUT IT. Alfred E. Phelps, M.D. With Introduction by R. Garfield Snyder, M.D. New York, Wm. Morrow & Co., 1943. $2.00.

This small book is written to give useful and accurate information about arthritis to the patient. It is written simply and clearly and contains no terms that should confuse the average layman. There are fourteen chapters on the various factors which play a part in the development of arthritis. The author has summarized the facts which we know about arthritis in an acceptable manner. More sketches or drawings would probably make the text more easily understood to those unfamiliar with the medical sciences. Some interpretation may be required by the patient's doctor. The discussion of treatment is colored somewhat by the writer's enthusiasm for gold and for large doses of Vitamin D. One would like to see a fuller discussion in the chapter "How the Patient can Help", on rest, exercise, worry and fear. This should be a helpful book for the average patient with arthritis.

A NEW METHOD IN THE TREATMENT OF TUBERCULOUS SPONDYLITIS. TRANSPLANTATION OF OS NOVUM IN ADDITION TO CHIPS OF EXCITED TIBIA AND THEIR OSTEOGENOUS TRANSFORMATION. Svante Orell. *Acta Chirurgica Scandinavica*, LXXXVI, Supplementum 69, 1942.

A well-illustrated ninety-six page monograph presents the adaptation of the writer's "os novum" bone graft to the spine. After preliminary identification of one of the spinous processes with a nail driven into it through a small skin incision, roentgenograms are taken. Under local anaesthesia, a unilateral exposure is obtained of half of the

spinous processes and the laminae of the affected vertebrae. Superficial cortical bone is removed. The articular processes are also "planed off". A massive graft is provided between the affected arches by using "os novum" next to the denuded bone, and, on top of this, multiple bone chips.

The "os novum" is prepared as previously described by placing *os purum* (prepared bone) under the periosteum of the tibia one to two months before the spinal operation. The skin is closed and a splint or plaster cast is applied to the leg.

At the time of the second operation, the graft of "os novum" is obtained by removing the implanted bone and adherent callus with a bone spatula. Multiple chips are then cut from the surface of the tibia. All of the grafts are temporarily returned to the wound which is closed with skin clips until the surgeon is ready for them.

Local anaesthesia is used throughout. The method has been used in twenty-eight cases of tuberculosis of the spine in patients who had been kept in plaster beds for variable periods of time. The patients were returned to the plaster beds after the operation. The writer suggests that in localized lesions not resulting in vertebral compression, osteosynthesis can be undertaken early with a good prognosis. When the disease is more widespread, with destruction of the vertebral bodies, rest in bed for twelve months or more should precede the operation.

A number of cases are reported in detail, and the results are analyzed in two charts. There is some variation in the technique. Frequently only two vertebrae are fused. The operation might better be called a modified technique than a new method.

THE EFFECT OF ROENTGEN IRRADIATION ON EPIPHYSEAL GROWTH. I. EXPERIMENTAL STUDIES UPON THE ALBINO RAT. Joseph S. Barr, James R. Lingley, and Edward A. Gall. *The American Journal of Roentgenology and Radium Therapy*, XLIX, 104, January 1943.

The sensitivity of the growing epiphyseal plate to small doses of roentgen rays is well known. Previous studies by Barr and his associates have shown the comparative effects of 200 and 1000 kilovolt roentgen rays on the skin, bone marrow, and epiphyses of albino rats. The present study was undertaken to determine (1) what dosage produces maximal effect on the epiphyseal plate without permanently damaging the juxta-epiphyseal tissues; (2) the effect of varying doses on longitudinal bone growth; (3) whether deformity, maldevelopment, or fragility occurs after such treatment.

To this end, a group of albino rats, thirty, ninety, and one hundred and eighty days old were subjected to roentgen irradiation (200 kilovolts) of one knee joint, and the resultant changes were studied histologically and roentgenographically. Doses of 665 to 1165 roentgen units produced moderately severe histological changes, while doses of 1335 to 1800 roentgen units caused very severe injury, as evidenced by disruption of the columns of cartilage cells and the destruction of the chondrocytes. Other tissues in the treated area—skin, subcutaneous tissue, muscle, synovial membrane, and articular cartilage—showed insignificant changes of a transitory nature. The hemapoietic elements of the bone marrow in the treatment field were diminished, but this local effect seemed to be of little significance to the organism as a whole. No degenerative or traumatic changes were noted in the treated joints even after nine months of observation.

Radiation retarded the longitudinal growth of the tibia in all the rats. The amount of retardation was roughly proportionate to the amount of radiation given. The larger doses produced complete arrest of the growth of the treated epiphysis.

Practical use of this information may possibly result in the correction or prevention of deformities in a leg paralyzed by anterior poliomyelitis. The present use of epiphyseodesis in the unaffected limb incurs some risk of wound infection, induced deformity, and other surgical complications. The substitution of roentgen irradiation as a means of limiting growth might conceivably offer advantages. However, the clinical application of these results must be deferred until a similar investigation in larger animals (dogs) is completed.—*Richard C. Batt, M.D., Berlin, New Hampshire.*

THE DIAGNOSIS OF POSTERIOR PROTRUSION OF THE INTERVERTEBRAL DISC. WITH SPECIAL REFERENCE TO (1) ITS DIFFERENTIATION FROM CERTAIN DEGENERATIVE LESIONS OF THE DISC AND ITS RELATED STRUCTURES AND (2) THE INTERPRETATION OF CONTRAST MYELOGRAPHY. Thomas Horwitz. *The American Journal of Roentgenology and Radium Therapy*, XLIX, 199, February 1943.

The author stresses the significance of degenerative lesions of the intervertebral disc and its related structures in the differential diagnosis of posterior protrusion of the intervertebral disc. From his experience with 100 spines of humans between the ages of forty and eighty he states his findings. Advanced degenerative disease often causes posterior bulging of the entire intervertebral disc without localized herniation. The disc may even protrude into the spongiosa of the adjacent vertebra without encroaching on the spinal canal at all. Or degeneration may be associated with a settling backward and downward of the upper vertebral body on the vertebral body below, so that the posteroinferior border of the upper vertebral body and the overlying disc material projects posteriorly into the neural canal. Further, the bulging forward of the ligamentum flavum, often constricting the intervertebral foramen, may be due to bony proliferation of the underlying facets of the apophyseal joint.

The majority of posterior disc protrusions have been observed between the fourth and fifth lumbar vertebrae and between the fifth lumbar and first sacral vertebrae. In this region the lesions are frequently asymptomatic because the canal is large and the cauda equina can be displaced considerably before pressure effects result. An intraspinal lesion in the cervical and thoracic regions, on the contrary, quickly compresses some conductive nerve pathway and expresses itself clinically.

While some believe clinical signs sufficient in the diagnosis of posterior protrusion of the intervertebral disc, the author favors myelography. A defect in the outline of the contrast medium, to be of significance, must be constant. The lesion is best visualized in the prone and prone-oblique views. The nerve roots are delineated by the opaque medium and any abnormalities are observed. Unfortunately, sometimes most of the damage lies beyond the neural canal and exploratory operation alone can determine its extent. However, in most cases roentgenographic diagnoses have been substantiated at operation.

THE OS EPIPYRAMIS OR EPITRIQUETRUM. R. L. de C. H. Saunders. *The Anatomical Record*, LXXXIV, 17, 1942.

The author calls attention to uncommon supernumerary or accessory carpal bones. The particular bone he describes was found wedged in between the triquetrum, lunate, hamate, and capitate, the medial articular facet articulating with the triquetrum, the lateral with the lunate, and the distal with the hamate and capitate. It is important not to confuse these accessory carpal bones with fractures. The existence of a synovial covered tag projecting into the joint cavity from the deep surface of the dorsal carpal ligaments introduces the possibility of metaplasia as a correct etiology for these bones. Fracture and metaplasia are ruled out in this example because of the bilateral symmetry of this particular bone; congenital origin is favored.

MALIGNANT TERATOMA OF THE ARM. CASE REPORT. C. J. Christy. *Annals of Surgery*, CXVI, 948, 1942.

The author reports a case of malignant teratoma in a white male, forty-nine years old. Twenty-five years previously, the patient had noticed on his left arm a small lump which had increased in size at first gradually, but in the last year and a half more rapidly. Physical examination was otherwise essentially negative. The provisional diagnoses were lipoma, fibrolipoma, and sarcoma.

Under 0.5-per-cent.-novocain anaesthesia, the tumor was removed *in toto* and a small gauze drain was inserted. The pathological diagnosis was malignant teratoma. The patient was discharged from the hospital the day of the operation, and his post-

operative recovery was uneventful. He was followed in the Out-Patient Clinic where he received daily doses of roentgenotherapy, through an anterior and a posterior field to a total of 3,564 roentgen units. More than a year later, the patient was well, had had no recurrence, and had returned to his former occupation.

STENOSING TENDOVAGINITIS AT THE RADIAL STYLOID (DE QUERVAIN'S DISEASE). Philip C. Potter. *Annals of Surgery*, CXVII, 290, February 1943.

De Quervain, in 1895, first called attention to the chronic and painful condition of stenosing tendovaginitis at the radial styloid. This is not to be confused with tuberculous tendovaginitis. The outstanding finding is a marked thickening of that portion of the dorsal carpal ligament overlying the tendon sheath of the abductor longus and extensor brevis pollicis. Sometimes this thickening results in an hour-glass deformity of the tendons. Fluid may be present under the tendon sheath.

De Quervain's disease, as it is called, is most generally the result of sustained or repeated active adduction from a position of extreme abduction. It is important to note that the causative factor is present in the handling of a gun over a prolonged period of time.

The primary symptom is extreme pain at the site of the radial styloid, which is increased by palpation over the affected tendon sheath. If the patient's thumb is placed in the hollow of the hand and grasped by the remaining fingers, even slight forced ulnar deviation at the wrist results in intense pain.

Preferred treatment consists of longitudinal division of that portion of the dorsal carpal ligament overlying the sheath. The tendon sheath, too, may be removed, but it is rarely necessary. Symptoms are eliminated by operation.

CONTINUOUS CAUDAL ANALGESIA IN SURGERY. James L. Southworth, Waldo B. Edwards, and Robert A. Hingson. *Annals of Surgery*, CXVII, 321, March 1943.

From their experience with 250 cases, the authors recommend continuous caudal analgesia, a method of prolonged caudal block, for operations in the fields of proctology, urology, orthopaedic surgery of the lower extremities, and gynecology.

The advantage of this method lies in the ease of administration, the relaxation of musculature obtained, and the slight interference with physiological processes and motor function.

The importance of accurately locating the sacral hiatus, into which the needle is inserted into the sacral canal, is stressed. Ten cubic centimeters of a 1.5-per-cent. solution of metycaine are used in the initial injection, followed by an average of fifty cubic centimeters, according to the size of the patient. Analgesia to the umbilicus is obtained within thirty to forty minutes. Twenty cubic centimeters are administered every thirty to forty minutes to sustain continuous analgesia. The time involved in obtaining complete analgesia constitutes the only disadvantage in the authors' opinion.

SHORT NOTES ON RHEUMATIC ARTHRITIS TREATED WITH MILK IODINE. P. K. Das. *The Antiseptic*, XXXIX, 588, 1942.

Das of Madras reports a series of eleven cases of arthritis, not due to syphilis, tuberculosis, or gonorrhoea, treated with injections of milk iodine in the gluteal region, in doses from five to ten cubic centimeters twice weekly, with very gratifying results. The ages of the patients ranged from forty to sixty years, and the duration of the disease was from three to eight years from onset. All patients began to show improvement after thirty cubic centimeters had been injected. It was found that urticaria could be prevented by preliminary injection of calcium lactate and adrenalin.—*Robert M. Green, M.D., Boston, Massachusetts.*

WAR MEDICINE AND SURGERY (Special Number). *The Antiseptic*, XXXIX, October 1942.

This issue is published as a special number on war medicine and surgery, and constitutes a valuable symposium on recent British experience in that field. N. E. James summarizes important aspects of the treatment of air raid casualties in London. T. H. Somervell discusses war surgery of the abdomen, C. S. S. Sarma of the chest, and M. G. Kini of the lower extremity. S. Sankara Raman advocates the Orr closed-plaster treatment of open fractures. K. V. Giri and P. Seshagiri Rao discuss war chemotherapy, K. S. Ranganathan discusses transfusion and infusion in the treatment of shock, U. Mohan Rau the treatment of war burns, and F. A. B. Sheppard gas gangrene. Martin Friedmann comments on measures for the control of venereal diseases, A. S. Mannady Nayar on kidney-function tests, and A. Narayana Menon on anaesthesia in war surgery. Robert Heilig and V. R. Naidu discuss typhus and its prevention. This issue may well be recommended to American physicians and surgeons in the armed forces and in civilian practice as a valuable summary compendium of recent British experience and observation.—*Robert M. Green, M.D., Boston, Massachusetts.*

PERI-ARTICULAR ARTHRITIS OF THE SHOULDER JOINT. P. S. Gupte. *The Antiseptic*, XL, 36, January 1943.

Gupte reports a case of periarticular arthritis of the shoulder joint, which he believes was due to focal infection and which has been treated successfully with vaccine.—*Robert M. Green, M.D., Boston, Massachusetts.*

EFFECT OF MASSIVE DOSES OF VITAMIN D ON CALCIUM AND PHOSPHORUS METABOLISM: OBSERVATIONS ON PATIENTS WITH ATROPHIC SPONDYLITIS AND WITH DEGENERATIVE ARTHRITIS OF THE SPINE. K. P. Klassen and G. M. Curtis. *Archives of Internal Medicine*, LXXI, 78, January 1943.

The experimental work published here was largely negative from the point of view of demonstrating either any fundamental alteration of the calcium and phosphorus metabolism in atrophic and degenerative arthritis, or any definite effect of massive doses of vitamin D on the balance between total intake and output of these elements. The serum inorganic phosphorus and calcium was slightly elevated in three of the four patients studied, and the authors warn against the indiscriminate use of large doses of vitamin D.

In two of the subjects, aged fifty-seven and seventy-one years, the diagnosis was degenerative arthritis of the spine; in the other two, aged twenty-eight and thirty-one years, the diagnosis was atrophic spondylitis. The patients were placed for thirty-six days upon controlled diets containing somewhat reduced amounts of calcium. Urine and faeces were collected for three-day periods. Serum calcium, inorganic phosphorus, phosphatase, and basal-metabolism observations were made at frequent intervals. Vitamin D was administered in doses varying from 200,000 to 1,000,000 U.S.P. units daily for a total of twelve days. There was a moderate increased retention of calcium in three patients, a decreased retention in one. The faecal loss of calcium was quite markedly decreased in three patients, and increased in one. The lower faecal excretion of calcium was in general compensated for by the increased urinary excretion. The excretion of phosphorus underwent somewhat similar changes to that of calcium.

The authors quite conservatively agree that there was shown no primary disturbance in the calcium and phosphorus metabolism in these patients. The changes in metabolic balance produced by vitamin D administration are in accordance with those demonstrated by others, and do not give much hope that this is a valuable therapeutic substance in arthritis. The authors are concerned with the question of thyroid and parathyroid behavior in arthritis, and the influence of vitamin D upon the function of these glands, but are unable to demonstrate any alteration in their activity.

Although the total exchange of calcium and phosphorus between the body and the

outside world does not show significant differences between the arthritic and the normal person, it is obvious that there are profound changes in the internal deposition of calcium and phosphorus. Roentgenograms of these patients were typical in showing calcification in some parts of the spine, and decalcification in others. A more profitable line of attack, than study of the total exchange, will have to be made to reveal the fundamental nature of this baffling group of diseases.—*Clark W. Heath, M.D., Cambridge, Massachusetts.*

Blood Flow in Extremities Affected by Anterior Poliomyelitis. P. I. Abramson, K. Flachs, J. Freiberg, and I. A. Mirsky. *Archives of Internal Medicine*, LXXI, 391, March 1943.

This work tends to disprove the theory that after poliomyelitis the blood flow of an affected extremity is diminished, and it casts doubt on the rationale of therapeutic methods attempting to improve a supposedly weaker circulation. Twenty-seven patients, who had recovered from active poliomyelitis for varying lengths of time, were the subjects. The peripheral circulation of the affected limb as opposed to the unaffected limb was studied by determining: (1) blood flow by the venous-occlusion plethysmographic method, (2) the response to arterial occlusion, and (3) cutaneous temperature. The blood flow per unit of tissue was not significantly altered on the affected side, being about as often increased as it was diminished. Critical analysis of the other findings also showed no significant differences.

The experiments were performed in the winter time, the patients being brought indoors for the purpose. It was found, particularly in the case of skin temperatures, that before the subject was thoroughly warmed the circulation on the affected side was smaller. Therefore, there was some evidence to corroborate the clinical impression of cooler skin surface and cutaneous vasoconstriction in the paralyzed extremity. The authors would do well to pursue their work by the study of dynamic changes in the circulation caused by heat, cold, and emotion, and by further study of the control of the autonomic nervous system.

Rigidly controlled experimental work requires the most careful consideration before being taken over in the clinic as useful fact. Interpretation is everything. In this case the authors have demonstrated beyond much doubt that under ordinary conditions there is not significant alteration in the circulation of paralyzed extremities in poliomyelitis. Clinically, it seems that methods designed to improve circulation in this disease, or otherwise to bring back useful function, should not be abandoned.—*Clark W. Heath, M.D., Cambridge, Massachusetts.*

Lesions of the Supraspinatus Tendon. Degeneration, Rupture and Calcification. C. L. Wilson. *Archives of Surgery*, XLVI, 307, March 1943.

The author emphasizes that degeneration, rupture of, and calcification within the supraspinatus tendon may cause disability for as long as two years.

He discusses the gross anatomy of the supraspinatus tendon, the other short rotator muscles of the shoulder, the tendon of the long head of the biceps muscle, and the subacromial bursa.

The function of the supraspinatus tendon is primarily that of abduction of the arm. When the deltoid muscle is paralyzed, the arm can be abducted. Even after rupture of the supraspinatus tendon, injection to remove pain makes abduction possible though much weakened. This tendon acts as an abductor of the arm up to the horizontal position, and from there as a stabilizer of the shoulder joint.

In microscopic study, muscle cells are seen to end abruptly in tendon cells. The supraspinatus tendon is inserted into the greater tuberosity of the humerus through a layer of fibrocartilage, called "the palisades" by Codman. The "critical portion",—the rupture point of the supraspinatus tendon, is the half inch proximal to the palisades.

Rupture occurs as a transverse tear in the fibers of the tendon. Incomplete rupture may occur on the joint side, where it is called a rim rent, on the bursal side involving the floor of the subacromial bursa, or within the substance of the tendon. A stub of the tendon, found attached to the greater tuberosity of the humerus after rupture, gradually wears away, and the tuberosity suffers erosion. The subacromial bursa is thick. There is exposure of the tendon of the long head of the biceps muscle.

Histological degenerative changes in the supraspinatus can be shown by staining. Degeneration leads to weakening of the tendon and eventual rupture under slight strain. It was demonstrated that a pull of 1000 pounds ruptured a normal supraspinatus tendon three millimeters thick and two centimeters wide.

Incidence of rupture is higher in males than in females, and though it may be bilateral, it is generally on the right side. Fracture of the greater tuberosity, instead of rupture, usually occurs in persons under fifty years of age. Degenerative changes and decreased vascularization, accompaniments of old age, may be the cause of the high incidence of rupture in persons over fifty. Trauma and wear may be precipitating factors. Whether occupation causes ischaemia or attrition still remains to be proved.

The clinical signs of rupture are pain at the insertion of the supraspinatus muscle, and inability to abduct the arm. Roentgenographic evidence is best obtained by chemical injection into the shoulder joint one centimeter anterolateral to the coraco-acromial joint, in the direction of the center of the head of the humerus. Rupture is indicated by either a finger-like projection flowing out of the joint cavity, or a free communication between the joint and the subacromial bursa.

Operation is the best treatment. A vertical incision one and one-half inches long is made over the anterior aspect of the head of the humerus with its upper end near the acromioclavicular joint and its lower end at the top of the bicipital groove. Repair is not difficult and the recovery period is two weeks.

Calcium deposits in the supraspinatus tendon are painful and irritate the surrounding muscles, tendons, and the subacromial bursa. Rupture into the bursa often results in cessation of pain and symptoms. The incidence of calcium is higher in males than in females, and highest in occupations requiring constant use of the arm in abduction. Trauma may be a contributing factor, but is not the cause of calcification. Onset may be insidious or acute. Roentgenograms do not always show deposits. The best treatment is immediate excision of the deposit. In chronic cases diathermy results in absorption of the calcium.

Subacromial bursitis never arises as a primary condition, but is the result of rupture of the supraspinatus tendon or other lesions in the surrounding tissues. It may be treated by hyperabduction or manipulation.

MISCONCEPTION ABOUT THE "SPRINGINESS" OF THE LONGITUDINAL ARCH OF THE FOOT. MECHANICS OF THE ARCH OF THE FOOT. Paul W. Lapidus. *Archives of Surgery*, XLVI, 410, March 1943.

The author takes issue with the long-held belief that the longitudinal arch of the foot operates as a spring, functioning by gradually absorbing shock as weight is placed on it, and elastically releasing as weight is removed. The plantar fascia in man is approximately fifteen centimeters long, and has a cross section of at least 0.5 square centimeters. The estimated tensile load of plantar fascia is thirty-five kilograms in a man weighing sixty kilograms, standing on one foot in a relaxed position. Maximum elongation of the fascia is only to 15.21 centimeters, 1.4 per cent. of its length, allowing for sagging of the apex of the arch of only 0.1 centimeters. The arch can thus hardly be compared to a "semielliptic spring".

The arch was really developed in response to functional requirements for increased strength of the foot as a lever. The foot is compared to a simple roof truss. The bottom is under tension; the upper part under compression. The higher the truss, the more it can stand tension and compression; the higher the longitudinal arch of the foot,

the greater tension and compression it can bear. The skeletal parts of the foot form struts which are subjected to compression stresses, and the plantar fascia acts as a tie rod taking up all the tensile stresses. Bending stresses are eliminated, and the strength of the foot as a lever is increased.

The integrity of the longitudinal arch is maintained by the ligamentous rather than by the muscle structure. In an anaesthetized subject there is no decrease in the height of the arch, and poliomyelitis causes no flattening of the arch. Protracted standing would be impossible if it were dependent upon the muscles, as they tire easily. Energy must be conserved.

The muscles of the legs further support the longitudinal arch of the foot, maintaining balance between the leg and the foot by keeping the weight-bearing line in the plumb line. They help bear weight and assist in locomotion.

Idiopathic "flat foot" is probably congenital or hereditary and not due to faulty muscle function.

MUSCLE TRANSPLANTATION FOR COMBINED FLEXION-INTERNAL ROTATION DEFORMITY OF THE THIGH IN SPASTIC PARALYSIS. Joseph S. Barr. *Archives of Surgery*, XLVI 605, May 1943.

Barr describes an operation for the relief of the flexion-internal rotation deformity of the thigh resulting from cerebral lesions of spastic birth palsy. The operation consists in freeing the tensor fasciae latae and the anterior thirds of the gluteus medius and gluteus minimus from the iliac bone and attaching them to the ilium posterior to the plane of the greater trochanter. Each of the patients operated upon during a period of ten years obtained satisfactory correction of the deformity.—*Albert Oppenheimer, M.D., Laconia, New Hampshire.*

EARLY MOBILIZATION OF FRACTURES OF THE UPPER END OF THE HUMERUS. Frank Brostrom. *Archives of Surgery*, XLVI, 614, May 1943.

Brostrom gives a very brief report of ninety-seven cases of fracture of the proximal end of the humerus, treated with passive motion from the fourth day after reduction on, and by active motion five to seven days later. The results were poor in six cases, fair in seventeen, good in thirty-two, excellent in twenty-seven, and undetermined in fifteen instances. The advantage over long immobilization consists in prompt relief of pain, prevention of secondary arthritis and stiffness, and in the fact that no elaborate equipment is needed.—*Albert Oppenheimer, M.D., Laconia, New Hampshire.*

PRONE POSITION FOR EXPOSING THE MEDIAL MENISCUS OF THE KNEE. Lewis Cozen. *Archives of Surgery*, XLVI, 616, May 1943.

For surgical removal of the medial meniscus of the knee, the author places the patient prone upon the table, with the knee flexed on the thigh. Spinal anaesthesia is used. No tourniquet is needed since bleeding is negligible in this position. Exposure of the posterior part of the meniscus is facilitated by this procedure.—*Albert Oppenheimer, M.D., Laconia, New Hampshire.*

NEW ASPECTS OF SPINAL INJURIES. Arthur G. Davis. *Archives of Surgery*, XLVI, 619, May 1943.

After discussing some of the general principles involved in the treatment of spine injuries, the author enumerates certain factors which he believes to be new. Among these is "roentgenographic concealment" of fractures of the neural arch (which, in the opinion of the reviewer, can be demonstrated if an adequate technique is used instead of the conventional roentgenograms shown by the author); a technique for reducing fracture-dislocation of the neural arch; and a "new" type of forward luxation of cervical vertebrae

(which was described by several other authors six or seven years ago). The author also stresses the importance of the great tensile strength of the anterior common ligament in the reduction of vertebral fractures and dislocations, a subject to which he made a noteworthy contribution in 1938. Good photographs illustrate his methods of reduction.—*Albert Oppenheimer, M.D., Laconia, New Hampshire.*

PSEUDARTHROSIS AND NEUROFIBROMATOSIS. William T. Green and Nathan Rudo. *Archives of Surgery*, XLVI, 639, May 1943.

The authors present a clear, accurate, and well-documented report of a case of deformity of the leg in a young child, caused by pseudarthrosis which developed following an unrecognized fracture of the fibula. This was later followed by fracture and pseudarthrosis of the tibia. Biopsies showed the bone in the regions of the non-united fractures to have been invaded by neurofibromatosis probably originating in the intra-osseous nerves. The authors conclude that, in the presence of "congenital pseudarthrosis", it is necessary to look for stigmata of neurofibromatosis, such as *café au lait* spots, extra-osseous tumors, and defects in other bones.—*Albert Oppenheimer, M.D., Laconia, New Hampshire.*

PAIN IN THE SHOULDER GIRDLE, ARM AND PRECORDIUM DUE TO FORAMINAL COMPRESSION OF NERVE ROOTS. Samuel S. Hanflig. *Archives of Surgery*, XLVI, 652, May 1943.

Hanflig refers to his own and to Oppenheimer's work on narrowing of the neural foramen as a cause of peripheral nerve pain. He believes that an inflammatory reaction accentuates the narrowing of the foramen which is caused by thinning of intervertebral discs. The symptoms are always the same, no matter what lesion caused the foramen to grow narrow. Pain in the shoulder and precordium, uninfluenced by motion of the shoulder but definitely related to motion of the neck, is the main symptom. The condition responds to traction either in the upright position or in bed. Neck traction in the upright position seems to be more effective. Photographs and roentgenograms illustrate the findings and the mode of treatment.—*Albert Oppenheimer, M.D., Laconia, New Hampshire.*

REHABILITATION IN WARTIME BRITAIN. Edward Harlan Wilson. *Archives of Surgery*, XLVI, 788, May 1943.

This is an account of the procedure used in the British Army for rehabilitation of wounded soldiers. One has to realize that the primary purpose of an army is to fight battles; the Medical Corps attempts to restore men to front line duty, and if this cannot be done, to discharge them, whereupon responsibility passes from the military to the civilian authorities. The British Ministry of Health furnishes completely equipped departments of physical and occupational therapy, conducted by an exceptionally well-trained staff. (The abstractor is in a position to confirm the unusually high standards of British-trained physiotherapists.) Knitting, weaving, and carpentry form the first steps of occupational therapy, and various forms of heat treatment are given at the same time. Later, when weight-bearing is begun, "P.T. sergeants", who are instructors in physical training, take over and put the convalescents through a limited drill designed to build up endurance and to overcome habitual limping. When healing is complete, the soldier is transferred to a rehabilitation camp, where his activity is increased rapidly. The author describes the rehabilitation camps of the Royal Air Force, largely organized by Watson-Jones, which he considers inspiring examples and recommends for adoption by the United States Army.—*Albert Oppenheimer, M.D., Laconia, New Hampshire.*

REHABILITATION IN AN E.M.S. ORTHOPAEDIC UNIT. S. Alan S. Malkin and Gilbert Parker. *British Medical Journal*, I, 315, March 13, 1943.

Orthopaedic Centres in the Emergency Medical Service have been established for rehabilitation. Patients are sent from the hospital to auxiliary hospitals where super-

vised exercise is combined with periods of freedom in which the patient walks around the grounds or indulges in swimming, croquet, etc. When patients have advanced out of plaster they are transferred to a Rehabilitation Annex. Knee-joint injuries are treated here by group drill to increase the power of the quadriceps. Faradism helps quadriceps contraction until the patient can induce it himself. Each week the power of the quadriceps is tested by weight and pulley, and the patient is discharged when the quadriceps of the leg which has been operated upon has regained power to 75 per cent. of the good leg. Occupational therapy is supervised by a sugical officer, who encourages the patient's interest in it. The patients are discharged only when they can return to active or semi-active duty, or are transferred to a Command Convalescent Depot to undergo graduated Army training. Some few have to be discharged from the Service as unfit for further duty.

Surgical Treatment of Osteomyelitis Due to a Penetrating Wound. George Perkins. *British Medical Journal*, I, 441, April 10, 1943.

The author advises varying treatment for (1) persistent acute osteomyelitis; (2) a sinus; (3) recurrent acute osteomyelitis (a flare); and (4) a sinus with flares. In persistent acute osteomyelitis due to a penetrating wound, drainage is sufficient and surgery is contra-indicated, unless life is in danger or the limb is crippled. If a sinus is present it may be due to a sequestrum or acute inflammation of the bone. The sequestrum should be removed only after inflammation of the soft surrounding tissues has died down. This usually removes the symptoms. Acute inflammation of the bone can be treated surgically, unless the entire bone area is affected. Recurrent acute osteomyelitis, not unlike an attack of malaria, flares up quickly and disappears as suddenly. Drainage of the bone and rest are advised. A sinus with flares defies treatment, and, if it persists in becoming a nuisance, amputation is the best solution.

Multiple Muscle Herniae. Ian D. Kitchin and David A. Richmond. *British Medical Journal*, I, 602. May 15, 1943.

The authors report several cases of multiple bilateral herniae of the tibialis anterior. They found the condition prevalent in soldiers located in mountainous districts, and it seemed to be associated with training in that locale. These herniae are easily distinguishable and hard to confuse with varicose veins. The splits in the fascia are distinctly felt and the herniae are easily reduced.

Leg Lengthening Operation: Its Present Status. Alvia Brockway. *California and Western Medicine*, LVIII, 11, January 1943.

As a result of twelve years' experience with 150 leg-equalization operations, the author believes that each of five methods has its place. Amputation with prosthesis is valuable in cases of poliomyelitis with severe paralysis and marked shortening, when the patient has sufficiently strong abdu or and extensor muscles to control an artificial leg. It is also valuable in a patient with a congenital shortening of four inches or more, and a small deformed club foot.

While epiphyseal stimulation in the short leg has support from some surgeons, the results on the whole have been disappointing. It is best used in the young child with a congenital short leg, when the leg discrepancy is increasing.

Epiphyseal arrest is gaining in favor. The operation is safe and the convalescence is short, but the results are not known until the end of the growth period, and the height at maturity is shortened.

Leg shortening, which should be done in the femur, has fewer complications and a shorter convalescence than leg lengthening, but it decreases stature and involves risk to the good leg.

Leg lengthening, which should be done below the knee, restores the stature which nature intended, and places the operation on the limb of poor function, but it may be accompanied by various complications. Of the author's 150 leg-equalization operations, 109 were for leg lengthening. He believes that leg shortening above the knee and epiphyseal arrest are now more common than leg lengthening.

War Surgery. Wallace H. Cole. *California and Western Medicine*, LVIII, 223, April 1943.

Because of the depth of the front lines in the present War, it is necessary to give first aid and then move the wounded far to the rear as quickly as possible. They cannot receive the more extensive primary treatment that was possible in the last War. This necessitates the use of the most effective types of treatment and immobilization that can be quickly accomplished at the Casualty Clearing Stations.

When complete débridement cannot be done, it is best to fix the part with plaster or Anderson pins, and hasten the patient back to the hospital, where the major work can be done. These pins may be left in for six months or more if necessary. After débridement, sulfanilamide is implanted into the wound. A method which has been very successful is to pack the wound with gauze impregnated with cod-liver-oil ointment mixed with sulfanilamide and sulfathiazole. This is very efficient, especially in old, infected wounds. The use of large quantities of the sulfonamides apparently does no harm, but, as they are very slowly absorbed, it appears to be a waste, because large flakes are often found in wounds weeks after implantation.—*Charles Lyle Hawk, M.D., Los Angeles, California.*

Decompression of Protruded Intervertebral Disks, With a Note on Spinal Exploration. Arthur Ecker. *The Journal of the American Medical Association*, CXXI, 401, February 6, 1943.

Exploration of the cauda equina in the region of the fifth lumbar vertebra for intractable low-back pain gives prompt and persistent relief in properly selected patients. Exploration should be adequate, and should usually include the anterior aspect of the spinal canal above and below the fifth lumbar vertebra in the mid-line and far laterally near the intervertebral foramen on each side. The author suggests the interlaminar approach to the spinal canal after bilateral stripping of the sacrospinalis from the spinous processes and laminae, and decompression of small intraspinal protrusions of intervertebral discs without removal of any of the disc structure. The importance of not opening the dura is stressed.

The author considers a disc protruded only if it bulges more when the lumbar spine is extended as a result of the anaesthetist's lifting of the patient's shoulders. It is not the protrusion of the disc which causes sciatic pain, but the compression of the nerve root between the disc and the posterior wall of the intervertebral foramen.

Questionable, slight, and moderate protrusions of the intervertebral discs should be left alone, and the overlying nerve root should be adequately decompressed. This procedure has yielded results as satisfactory as removal of the protruded portions of such discs, and it may minimize the incidence of the recurrence of symptoms.—*John K. Coker, M.D., Dallas, Texas.*

Tumoral Calcinosis. Alberto Inclán, with the collaboration of P. Leon and M. Gomez Camejo. *The Journal of the American Medical Association*, CXXI, 490, February 13, 1943.

The author presents three unusual cases of a calcified growth of unknown etiology and pathogenesis under the name of tumoral calcinosis or calcareous granuloma.

Each of the tumors was resected and thoroughly studied. Each of the patients was also thoroughly investigated. All possible parasitic infestations, systemic, local, and metabolic diseases, and neoplasms, both benign and malignant, were eliminated.

All three patients were negroes; two had no pain; there were calcifications in other structures, no skin changes, no involvement of joints, and no deformities, rigidities, contractures, or disturbances of gait. All three tumors were of rapid growth, apparently arising from bursae, and subsequently invaded the surrounding muscle.

These tumors were found in the left gluteal region, about the right triceps tendon, and over the sacrum and the left gluteal region. All had reached the size of an orange or grapefruit. All were mixtures of cells or cavities containing fluid resembling magma magnesiae and areas of putty-like consistency which gave a gritty sensation when cut. They were treated by excision and high-voltage roentgenotherapy, with limitation, arrest, or cure of the lesion.—*Joseph H. Reno, M.D., Dallas, Texas.*

On the Aetiology of Acute Rheumatic Fever. E. G. H. Koenigsfeld. *Journal of the Indian Medical Association*, XII, 112, January 1943.

Koenigsfeld concludes, from a clinical study of acute rheumatic fever, that within this clinical entity are two similar diseases of different etiology,—specific acute rheumatic fever caused by an ultravisible virus, and streptococcal arthritis. The two diseases may be differentiated histologically by the presence of Aschoff's nodules in connective tissue in acute rheumatic fever and their absence in streptococcal arthritis. They may be differentiated, also, by their complications. The complications of acute rheumatic fever are usually endocarditis simplex, verrucosa (no streptococcus in the endocardium), chroea, and iritis rheumatica, while those of streptococcal arthritis are usually endocarditis ulcerosa (streptococcus present in the endocardium), purulent meningitis, and purulent iritis or panophthalmitis. Acute rheumatic fever, he finds, responds in treatment to salicylic acid, and streptococcal arthritis to sulfanilamide. This therapeutic test, the author suggests, may be used in differential diagnosis.

The author admits that all clinical cases do not permit such a clear distinction, because both conditions may be present at the same time.—*Robert M. Green, M.D., Boston, Massachusetts.*

Compression Fractures of the Spine. W. P. Sammons. *The Journal of the International College of Surgeons*, V, 300, 1942.

Six per cent. of all fractures occur in the vertebral column, chiefly in the upper cervical, upper thoracic, and thoracolumbar regions. While fractures occur at all ages, they are most frequent during the third and fourth decades.

The diagnosis and treatment of hyperextension fractures, fractures with cord injury, fractures of the cervical region, and paraplegia are discussed. Of various methods of achieving hyperextension, the author prefers the Watson-Jones method. The mental state of the patient is the most important factor. Daily exercises are imperative to prevent muscle-wasting.

Propamidine in Chronic Wound Sepsis. W. R. Thrower and F. C. O. Valentine. *The Lancet*, I, 133, January 30, 1943.

The authors point out that in established wound sepsis the local application of sulfonamides is of limited value, mainly because their action is inhibited by the peptones and other constituents of pus and tissue fluid. The bacteriostatic action of propamidine, an amidine, proved not to be inhibited in this way. The authors carried out *in vitro* experiments on several strains of staphylococcus aureus and hemolytic streptococcus. In their clinical studies, they used ten cases which illustrated the efficacy of the local use of this amidine. The authors described in detail the technique of applying the drug in a watery gel of methyl cellulose. They conclude that propamidine possesses a bacteriostatic activity against staphylococcus aureus of the same order as sulfathiazole. Effective concentrations do not inhibit phagocytosis or cause hemolysis. The bacterial

effect of the drug is not seriously lessened by the presence of pus.—*Lenox D. Baker, M.D., Durham, North Carolina.*

REHABILITATION AFTER MENISCECTOMY. J. J. R. Duthie and J. G. MacLeod. *The Lancet*, I, 197, February 13, 1943.

The authors, who are attached to a large Army Convalescent Depot, analyzed 186 consecutive cases admitted for rehabilitation following meniscectomy. On admission, obvious wasting of the quadriceps was evident in 75.2 per cent., and some limitation of flexion at the knee joint in 50 per cent.; an effusion was present in 33 per cent., and there was a laxity of the cruciate ligament in 24 per cent. The patients were put through remedial exercise and physical training during two periods each day. The remedial exercises were largely concerned with quadriceps development. Among the exercises were those of the weight-pulley type. The average stay in the hospital after meniscectomy was forty-seven days, the average stay in the Convalescent Depot was thirty-five days, the average of the total time off duty was eighty-two days. From the results of the study it was concluded that strength is restored to wasted quadriceps after meniscectomy more rapidly by resisted exercises of the weight-pulley type than by non-resisted exercises.—*Lenox D. Baker, M.D., Durham, North Carolina.*

GENERAL AND LOCAL ADMINISTRATION OF PENICILLIN. H. W. Florey and M. E. Florey. *The Lancet*, I, 387, March 27, 1943.

The authors report fifteen cases of serious illness treated with penicillin by mouth or by intravenous or intramuscular injection. No toxic symptoms due to the drug were met. The authors state that it is clear from this series that a generalized staphylococcus infection can be cured by penicillin, and that local lesions heal during parenteral administration. The healing of bone lesions is particularly striking. Local penicillin treatment was used in 172 infections of the eye and mastoid process, chronic wound sinuses, and miscellaneous local septic conditions. In most cases, after adequate treatment, staphylococci and streptococci were eliminated, with subsequent healing. While the supplies of penicillin will not permit the treatment of more than a few cases by general administration, the uses of local application are being further explored.—*Lenox D. Baker, M.D., Durham, North Carolina.*

RUPTURE OF THE SEMILUNAR CARTILAGES OF THE KNEE JOINT, OSTEOCHONDRITIS DISSECANS AND HALLUX VALGUS AND RIGIDUS. THE RESULTS OF OPERATIVE TREATMENT AND THE SIGNIFICANCE OF THESE DISABILITIES IN THE 2ND N. Z. E. F. T. D. M. Stout. *New Zealand Medical Journal*, XLI, 130, 1942.

In this article a survey is made of all cases of these conditions occurring in members of the Second New Zealand Expeditionary Force.

The patients, most of whom had been operated upon, were classified according to functional ability into three groups: (1) those able to return to full military duty; (2) those unfit for front-line service, but able to perform some duties at the Base; and (3) those evacuated to New Zealand as unfit for any military service.

Of the thirty-five patients with rupture of the medial meniscus, 13 per cent. were evacuated, 16 per cent. remained at the Base; and 71 per cent. returned to full military duty. Of fifteen patients with rupture of the lateral meniscus, 23 per cent. were evacuated, 15.4 per cent. remained at the Base, and 61.6 per cent. returned to full duty. Of seven patients with osteochrondritis dissecans, one was evacuated, two remained at the Base and three returned to full duty. Of twenty-six patients with hallux valgus, five had radical operations (one before the War); two were evacuated, two remained at the Base; and one returned to full duty. Ten patients had exostoses or bunions removed, and returned to full duty. No operation was performed in eleven cases; five of the pa-

tients were evacuated, and six remained at the Base.—*Major H. Walden Fitzgerald, Dunedin, New Zealand.*

SURGICAL CONSIDERATION OF WAR CASUALTIES. W. H. Beermann. *Northwest Medicine*, XLII, 67, March 1943.

Today civilians are subject to the same type of casualties as are the armed forces. The wounds may be much more severe than is apparent on the surface, especially in the abdomen. High-velocity bullets or bomb fragments produce explosive-like damage to viscera which may extend as much as six inches lateral to the course of the missile. Rifle projectiles travel as high as 2,800 feet per second. The revolver and submachine-gun bullets travel only one-third to one-half as fast, while the smaller fragments from an exploding bomb may reach 5,000 feet per second. Such fragments, being very irregular and highly erratic in motion, may enter the abdominal or chest wall and leave only the smallest scratchlike lacerations, but they do great damage beneath the skin.

Conservative treatment is contra-indicated. Débridement should be done within six hours,—before the tissues become infected by contamination. Hence the time element following injury may determine the nature of the treatment. Too much emphasis cannot be placed upon careful examination of the integument and roentgenographic findings. In cases less than twelve hours old, there should be thorough cleansing with soap and water, and early excision of wounds; in older cases, only removal of foreign bodies and total immobilization is indicated. Sterile flavine-soaked gauze or gauze soaked in honey and cod-liver oil is advocated to fill the wound for drainage, and the wound is to be kept open. The use of sulfonamides has been found to clear granulating wounds of streptococcal infection in a few days. In penetrating abdominal wounds, early exploration and repair are imperative. "Sucking" wounds of the chest are most satisfactorily treated at the Casualty Clearing Station by gauze compresses, held in place by deep silkworm sutures.

It is astonishing how few head wounds cause unconsciousness. This is because of the action of swift-moving missiles, which cause skull injury without moving the head the necessary twenty-three feet per second required to produce unconsciousness.—*Charles Lyle Hawk, M.D., Los Angeles, California.*

TREATMENT OF WAR WOUNDS AND FRACTURES. Ignacio Ponseti and Joseph Puig Guri. *Northwest Medicine*, XLII, 73, March 1943.

The authors describe at length the various principles underlying tissue infection, and the various surgical procedures in infected wounds, and simple and compound fractures. These include rest and functional treatments, unpadded casts, and skeletal traction. Open and closed methods of treatment of infected wounds are discussed. These are correlated with the authors' experiences in the Spanish War.—*Charles Lyle Hawk, M.D., Los Angeles, California.*

PROGRESS FROM WAR SURGERY. Charles R. McCreery. *Northwest Medicine*, XLII, 78, March 1943.

This is a discussion of the various lines of progress in war surgery, including the uses of sulfonamides and dried blood serum. The author cautions against the use of tannic acid in severe burns of the face and extremities, especially of the digits, as the resulting eschars are likely to interfere with the circulation. He advises the use of saline and vaseline dressings in these areas.

More compound fractures are seen in this War than in the last. In conjunction with favorable reports from the Orr treatment in these cases, the author says, "Some authorities report a large number of malunions, and many cases of arthritis". The present use of the aeroplane lessens the period between injury and adequate treatment of the wounded, resulting in more favorable recoveries.—*Charles Lyle Hawk, M.D., Los Angeles, California.*

AMPUTATION ANAESTHESIA BY FREEZING. Edwin A. Nixon. *Northwest Medicine*, XLII, 131, May 1943.

There are several advantages arising from this form of anaesthesia: less shock, lower mortality, less postoperative pain, healthier tissue healing, and theoretically lessened bacterial growth in infected cases. A sedative, such as a small dose of morphine or an H.M.C. No. 2, is given thirty minutes before icing. The refrigeration is accomplished by packing the part in ice for from two to two and one-half hours, until the skin temperature has reached two to five degrees centigrade. A pneumatic tourniquet with a gauge is imperative, and does no harm in arteriosclerosis, even when left on for from two to four hours.

After amputation, ice bags are placed around the stump for four days. Defrigeration is gradual, and the after pains are lessened. The stitches must remain longer than usual because of the slower healing. This form of anaesthesia is most suitable for patients who are bad risks, including those with diabetic gangrene. It is also suitable for skin-grafting operations.—*Charles Lyle Hawk, M.D., Los Angeles, California.*

MANAGEMENT OF TRAUMATIC INJURIES OF THE HAND. Wilbur B. Hutchinson. *Northwest Medicine*, XLII, May 1943.

The author stresses the necessity of adhering to certain fundamentals in hand injuries. If seen within four to six hours after injury, the contaminating bacteria will not have invaded the tissues, and thorough cleansing with soap and water is imperative. Judicial débridement follows. Nerves and tendons are sutured primarily and covered with fascia. The hand is then splinted, not encased in plaster, in the functional position.—*Charles Lyle Hawk, M.D., Los Angeles, California.*

AN AXIAL VIEW OF THE HEAD OF THE RADIUS. A. J. Sheffrin. *Radiography*, IX, 20, March 1943.

A roentgenographic method for demonstrating the head of the radius is described. The patient, sitting, places his elbow on the film so that the humerus rests on the film and the forearm is bent, forming an angle of 70 degrees with the horizontal plane, one view being taken in the position of supination, the other in pronation. The central ray points vertically downward and passes midway between the epicondyles. This abstractor has found the procedure described valuable in aiding the roentgenologist and orthopaedic surgeon to make an accurate diagnosis of injuries of the elbow region, especially the head of the radius. The method was developed by an x-ray technician of the British Army Medical Corps.—*Albert Oppenheimer, M.D., Laconia, New Hampshire.*

A SURVEY OF HODGKIN'S DISEASE AND LYMPHOSARCOMA IN BONE. J. O. Vieta, H. L. Friedell, and L. F. Craver. *Radiology*, XXXIX, 1, 1942.

Routine autopsy protocols of forty-seven cases of Hodgkin's disease and fifty-four cases of lymphosarcoma were reviewed.

In Hodgkin's disease twenty-three of the forty-seven cases (49 per cent.) were found to have skeletal lesions. In only eight (34 per cent.) of these twenty-three cases, did the lesions continue on to actual cortical destruction, while in lymphosarcoma, ten of the sixteen cases (63 per cent.) showed true bone destruction. It is concluded from these figures that cortical destruction is more likely to be a feature of osseous involvement in lymphosarcoma than in Hodgkin's disease. Involvement of bone marrow alone, without cortical destruction, was found in fifteen of twenty-three cases of Hodgkin's disease, and in six out of sixteen cases of lymphosarcoma.

In a review of 257 cases of Hodgkin's disease, roentgenographic evidence of bone involvement was found in thirty-eight cases (14.8 per cent.). A similar study of 213 cases of lymphosarcoma showed roentgenographic evidence of bone changes in fifteen cases (7 per cent.).

In a survey of 498 cases of Hodgkin's disease, the peak in age incidence was found to lie between twenty and twenty-four years, and the mean to lie between thirty-two

and thirty-six years. In 398 cases of lymphosarcoma, the peak in age incidence was between fifty-two and fifty-six years, and the mean approximately forty-eight years.

An attempt was made to determine at what point during the course of the disease osseous lesions occur, and a review was made of forty-four cases from the inception of the disease until death. Thirty-seven per cent. of the patients showed osseous lesions before one-half of the course of the disease had lapsed. In 31 per cent. these developed in the last third of the course. The average duration of life after occurrence of bone lesions in these forty-four cases was seventeen and six-tenths months.

Bone lesions developed in 22 per cent. of twenty-seven cases of lymphosarcoma in the first half of the span of the disease, while in 63 per cent., involvement appeared in the final third of the course.

The lesions were most frequently found in the pelvis, vertebrae, ribs, and femora, and in most cases involved more than one bone.

Localized pain and tenderness were the most frequent clinical indications of bone lesions, but tumors about the bone margins and neurological changes due to extension into the spinal canal from vertebral lesions were also observed. Elevated serum phosphatase may be considered an index of bone extension from both lymphosarcoma and Hodgkin's disease.

The lesions were predominantly of the mixed type in Hodgkin's disease, 57 per cent. showing a combination of osteoplastic and osteolytic changes. In lymphosarcoma, however, 85 per cent. were entirely osteolytic. Lesions in Hodgkin's disease involved a greater number of bones and were more numerous, but the lesions of lymphosarcoma were more invasive.

In lymphosarcoma, no difference in survival rates was observed in patients with and without bone lesions, whereas in Hodgkin's disease, those with bone changes appeared to have a longer average survival.

Radiation therapy offers definite amelioration of symptoms in the osseous lesions of Hodgkin's disease, and in some cases completely restores the invaded bone to its normal structure. Similar clinical improvement occurred in lymphosarcoma after radiation therapy, but no opportunity to follow the bone changes was available because of the short average survival after skeletal invasion.—*Julius Y. Sher, M.D., Iowa City, Iowa.*

Osteogenesis Imperfecta. William H. Bickel, Ralph K. Ghormley, and John D. Camp. *Radiology*, XL, 145, February 1943.

Called by various names, fragilitas osseum, brittle bones, blue sclera and otosclerosis, etc., these cases are divisible into (1) the hereditary type, which is called an hereditary hypoplasia of the mesenchyme with brittle bones and blue sclera, and (2) the non-hereditary, congenital type comprising two groups: osteogenesis imperfecta congenita and osteogenesis imperfecta tarda. Blue sclerae, while requisite for the first group, may or may not be present in the second.

As to etiology, Knaggs has stated that there is an evolutionary failure of the osteoblasts; Key and others have attributed all the changes to heredity; the endocrine glands have been implicated, but the evidence is inconclusive. There is probably some inherent defect in the germ plasm, hereditary or non-hereditary, which does not allow the mesenchymal tissue to develop normally.

The present study is of forty cases seen at the Mayo Clinic from 1920 to 1940. Clinically, it is impossible to distinguish between the hereditary type and the non-hereditary, congenital type. Of the cases studied, 27.5 per cent. were of the hereditary type, in one family involving four generations, all presenting brittle bones, blue sclerae, and deafness. Transmissible by either the male or female, the defect follows mendelian characteristics. Once transmission has begun, no generation is without some stigma of the disease. In 72.5 per cent. of the cases, there was no family history of the disease. Few of the non-hereditary, congenital type live to a great age, and many are so badly crippled they do not marry.

There is great variation in the severity of the process, some coming under observation

for conditions entirely unrelated to skeletal defect. On the whole, these patients were poorly nourished, short, and presented many deformities.

Multiple fractures occurred in all cases, and, with one exception, were caused by slight trauma and were less painful than usual. Four hundred and thirty-four fractures were recorded in the forty cases, forty-six being recorded in one case, while in seven they were too numerous to record. The long bones were usually involved, though no bone was exempt. In the non-hereditary type they were more frequent, and occurred earlier and with less trauma than in the hereditary type. Usually of the subperiosteal type, the fractures showed little displacement, but marked angulation. One of the authors (Camp) believes that the majority of the so-called fractures reported in this condition are really pseudofractures or Looser's Zones. The frequency of fractures decreased as puberty was approached, and in some cases fractures ceased after puberty.

Osteogenesis imperfecta may occur without blue sclerae.

Deafness occurred in 45.5 per cent. of the hereditary type, and in 17.3 per cent. of the non-hereditary type; the higher incidence in the former is explained probably by the greater age to which these patients live, the otosclerotic type of deafness to which they are subject having time to develop.

Routine laboratory examinations of urine and of blood gave consistently normal findings.

Tissue for histological study was obtained from one case only. A detailed description of the findings is given.

A comprehensive report of roentgenographic findings is made.

Treatment is reported as having attained no conclusive success.—*Edward N. Reed, M.D., Santa Monica, California.*

Osteopetrosis (Albers-Schönberg Disease), with Case Report. Carl A. W. Zimmermann, III. *Radiology*, XL, 155, February 1943.

This is a disease characterized by unlimited calcification of bones. The bony overgrowth often encroaches upon the foramena of exit of cranial nerves, producing, at times, blindness from atrophy of the optic nerve, deafness, or facial paralysis. The disease is characterized by stunted growth, hydrocephalus, mental hebetude, headache, nausea, vomiting, frequent fractures, and blood dyscrasias due to encroachment on the bone marrow.

Few cases of the disease have reached an advanced age; therapy offers no hope.

The etiology is unknown. Its origin is probably antenatal, and it is progressive as age advances. A history of consanguinity in the parents is frequent, as is hereditary sequence.

The theory of an endocrine origin is discarded. Herscher and Stein favor the theory of "an hereditary defect in the germ plasm, carried as a mendelian recessive factor and accentuated by inbreeding". Pathological and roentgenographic features are: great bone density which invariably has involved the base of the skull; fractures occurring from slight insults; bad teeth; and great irregularity of bone structure, with notable deficiency in the number of osteoblasts. The blood chemistry has shown no consistent departure from the normal.

A detailed report is given of one case, believed to be the 120th to be reported in the literature.—*Edward N. Reed, M.D., Santa Monica, California.*

A Correlation of Roentgenogram and Pathological Changes in Ossifying and Chondrifying Primary Osteogenic Neoplasms. J. Vernon Luck. *Radiology*, XL, 253, March 1943.

This paper describes the histological characteristics, the manner of development, histogenesis, and metaplasia of the tumors included by the title, together with their roentgenographic appearances and characteristics. It is an excellent article and well illustrated but it does not lend itself to condensation or abstraction.—*Edward N. Reed, M.D., Santa Monica, California.*

FLUORIDE OSTEOSCLEROSIS FROM DRINKING WATER. Joseph F. Linsman and Crawford A. McMurray. *Radiology*, XL, 474, May 1943.

The authors stress the danger of severe anaemia, which may result from fluorine osteosclerosis. This disease, prevalent in the southwestern and middle western states, where fluorine content of the water exceeds three parts per million, is characterized by increased density of the bones, which present a chalklike appearance; thickened bone trabeculae; a susceptibility to infection; and anaemia. The bones of the trunk are affected most, probably due to the greater metabolic activity in bones in which hemopoiesis is taking place. Dental fluorosis is present only when the patient has lived during the first seven years of life where the fluorine content of the water is high. Oddly enough, dental caries is limited by mottled enamel,—dental fluorosis.

The anaemia accompanying fluorine osteosclerosis does not respond to liver therapy and appears to be a result of the encroachment of thickened trabeculae on the bone marrow. The reduced blood supply leaves the patient open to infection where the body is weakest. In the patient which the authors describe, the one parathyroid gland present appeared to be slightly enlarged grossly.

It is interesting to note that the fluorine content of water is high in North Africa and India.

TRAUMATISMOS DE LA COLUMNA VERTEBRAL Y DE LA MÉDULA POR AGENTES BÉLICOS (Injuries of the Spine and Cord by Agents Encountered in Warfare). Enrique Robiou García. *Revista Mexicana de Cirugía, Ginecología y Cáncer*, X, 27, 1942.

The author points out the importance of studying and analyzing war injuries of the spine and spinal cord in order to determine the type of treatment to be used and the prognosis. He discusses the three types of lesions which may occur, singly or in combination: concussion of the cord, fractures or dislocations, and wounds of the cord. There are two types of spinal concussion,—indirect and direct. The indirect was formerly thought to be due to a psychoneurotic shock, but has been found to be due to definite involvement of the cord not associated with external evidence of violence. In the direct type of concussion, there is a blow with external evidence of injury and more definite anatomical pathological lesions. In these there is often a clinical block with temporary quadriplegia. The diagnosis is confirmed by a negative or nearly negative spinal puncture and negative roentgenograms. The prognosis is generally good, and the treatment is expectant and symptomatic. There then follows a general discussion of fractures of the spine, with and without dislocation. Incomplete fractures of the neural arch usually give rise to partial cord compressions, while complete fractures of the neural arch cause complete sections of the cord. He states that all fractures and dislocations of the vertebral column have an accompanying focal hematomyelia, either single or multiple. Signs and symptoms of various cord lesions are discussed. Roentgenograms are all-important in these cases. The prognosis is good in cases with only a saddle anaesthesia, but very poor with complete severance of the cord. In the former type surgical intervention is indicated, but in the latter only if an impinging piece of bone is present. In the third main type of lesion—direct wounds of the spinal cord—the most important is complete section of the cord. In these cases there are three stages: (1) the stage of complete paralysis and spinal shock, (2) the stage of automatic reflex spinal movement, and (3) the terminal stage with complications, such as pneumonia, urinary infection, and anaemia. The diagnosis is based on the evolution of the three stages of the symptomatology. The prognosis is very poor and the treatment consists principally of avoiding infection.—*Captain Louis W. Breck, Medical Corps, Fort Sam Houston, Texas.*

EQUALIZING THE LOWER EXTREMITIES: A CLINICAL CONSIDERATION OF LEG LENGTHENING VERSUS LEG SHORTENING. George S. Phalen and C. C. Chatterton. *Surgery*, XII, 768, 1942.

The authors refer to the psychological and physical difficulties developing from a shortened lower extremity, and discuss the advantages, disadvantages, and techniques

of various methods of leg-lengthening and leg-shortening operations, and the indications and contra-indications for their use.

Before the operation for leg lengthening is performed, the patient should wear an elevated shoe not only to correct secondary conditions such as scoliosis and poor posture, but also to determine the amount of lengthening which will give the optimal improvement in function. In some instances, a leg-lengthening operation may so change the leverage of weakened muscles that the gait will be worse rather than better after the operation.

The article is based on the authors' experience with forty-five patients, twenty-six of whom had leg-lengthening, and nineteen, leg-shortening operations. The authors prefer leg-shortening operations, and believe that the leg-lengthening procedures should be limited to a small, carefully chosen group of patients who are either unwilling or ill able to sacrifice any fraction of their height.

CONGENITAL NARROWING OF THE LUMBOSACRAL SPACE. Theodore H. Vinke and Edgar H. White. *Surgery, Gynecology and Obstetrics*, LXXVI, 551, May 1943.

The roentgenograms of the lumbosacral junction in 300 children between the ages of five and fifteen years were studied. All cases in which there was any evidence of fracture, infection, trauma, or those in which roentgenograms were not technically satisfactory, were discarded. It was the opinion of the authors that any narrowing occurring in this age group must be of congenital origin, since destructive changes incident to trauma would be less likely encountered in children. Three such cases were disclosed. Six case histories of adults were then reviewed. All six patients had pain which could be adequately explained on a basis other than herniation of the intervertebral disc. The absence of neurological changes, plus the excellent response to conservative management, were evidence against a pathological process in the disc. With the recent emphasis which has been placed upon the making of the diagnosis of the herniated intervertebral disc without the use of lipiodol or other contrast media, it would be reasonable to believe that the presence of a narrowed intervertebral space in doubtful cases might give the operator a false sense of security.—*Carroll B. Larson, M.D., Boston, Massachusetts.*

INTERNAL FIXATION IN INJURIES OF THE ANKLE. Harold G. Lee and Thomas B. Horan. *Surgery, Gynecology and Obstetrics*, LXXVI, 593, May 1943.

The authors have discussed the necessity for accurate reduction in fractures about the ankle, and have pointed out the frequency with which open reduction is necessary in order to accomplish an anatomical restoration. They have taken up separately: fracture of the lower end of the fibula, trimalleolar fracture, fracture of the anterior tibial surface, fracture of the internal malleolus, Pott's fracture, separation of the tibia and fibula, and recurrent dislocation of the peroneal tendons. In each of these various conditions the authors have pointed out the important disalignments to be corrected and the necessity for internal fixation. In nearly every instance they have accomplished this fixation by the use of a strategically placed bone screw. They feel that it is important that operative indications be recognized promptly, and that manipulative treatment be avoided. A classification of those injuries which require operative treatment is presented, and methods that have given excellent results are described.—*Carroll B. Larson, M.D., Boston, Massachusetts.*